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PRECISION SOUND VELOCITY PROFILES IN THE OCEAN

VOLUME VI

SOUND SPEEDS AND TEMPERATURES IN AND NEAR THE DEEP PASSAGES OF THE EASTERN CARIBBEAN (November 1966-July 1967)

by

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ABSTRACT

High precision, high resolution sound speed and temperature profile sequences are presented for 7 near-synoptic stations in the Anegada passage region; 8 near-synoptic stations in the deep passages adjoining Martinique (St. Lucia and Dominica channels); and 4 stations in the Atlantic about a degree east of the Antillean islands. Microstructure of the waters and short-time variability are emphasized.

Stratification and variability in the passages and the Atlantic nearby are more intense than in the Caribbean.

The characteristics of the Anegada region are intermediate between the Caribbean and the Atlantic. A distinct inflow of Atlantic waters occurs at a kilometer's depth.

Around Martinique the waters are extremely stratified and very confused, the Caribbean dominating nearly to the eastern side of the passages. At the time of this report, the region was influenced by a cold water mass between 160 and 600m depth. This unusual transient water mass, centered east of St. Lucia, is described.

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LIST OF STATIONS AND FIGURES

Chart of Stations: Fig. 1

STATION NUMBER	POSITION North	POSITION West	DATE	# OF PROFILES	FIGURE NUMBER: PROFILES SOUND SPEED	FIGURE NUMBER: PROFILES TEMPERATURE	FIGURE NUMBER: ENVELOPES
120	19°45'	63°46'	18 Nov 66	4	2	3	40
121	18°45'	63°27'	19 Nov 66	4	4	5	41
122	18°55'	64°04'	19 Nov 66	4	6	7	42
123	18°48'	63°41'	19 Nov 66	4	8	9	43
124	18°02'	64°16'	20 Nov 66	4	10	11	44
125	18°02'	64°47'	20 Nov 66	4	12	13	45
126	17°00'	64°30'	21 Nov 66	4	14	15	46
132	22°00'	61°49'	13 Jun 67	2	16	17	47
133	18°05'	60°54'	14 Jun 67	4	18	19	48
134	14°15'	59°57'	15 Jun 67	4	20	21	49
139	12°56'	59°09'	10 Jul 67	2	22	23	50
140	13°53'	60°24'	14 Jul 67	4	24	25	51
141	14°15'	60°27'	14 Jul 67	4	26	27	52
142	14°28'	61°13'	15 Jul 67	2	28	29	53
143	14°17'	60°49'	15 Jul 67	4	30	31	54
144	14°17'	61°05'	15 Jul 67	4	32	33	55
145	14°59'	61°28'	15 Jul 67	4	34	35	56
146	15°04'	61°19'	16 Jul 67	4	36	37	57
147	15°34'	60°53'	16 Jul 67	4	38	39	58

INTRODUCTION

Of the innumerable passages connecting the Caribbean to the Atlantic, only 4 are deep enough to have a sill depth of the order of a kilometer. Three of these are on the fringes of the Venezuelan Basin: the two passages south and north of Martinique, St. Lucia Passage and the Dominica Channel; and Anegada Passage, 3-400 miles northwest of these two, separating the Lesser from the Greater Antilles. The fourth deep passage, Windward Passage, lies between Cuba and Hispaniola, 4-500 miles west of Anegada.

In this report we are concerned with the three eastern passages, which were investigated in some detail during two cruises of our R/V SIR HORACE LAMB. In November '66 we spent several days around Anegada and the Virgin Islands; in July '67 we were around Barbados and Martinique and took a concentrated series of stations in and near the Martinique passages.

In addition to the stations in and close to the three passages, a few stations at considerable distance have been included to illustrate conditions in the open or relatively open ocean on both the Atlantic and Caribbean sides.

For each of our stations several consecutive high-resolution sound speed and temperature profiles are shown. These demonstrate the acoustic and thermal stratification of the waters in considerable detail, and changes that occur in a few hours.

Although the passages are of relatively small importance to the underwater acoustician, they are interesting to the hydrologist. It is largely for their benefit that we show our whole series of sound speed profiles. Detailed, accurate sound speed profiles provide a rapid and detailed picture of the water stratification, qualitatively more than quantitatively: sound speed depends strongly on temperature ($1 m/s \simeq 0.28^\circ C$), salinity ($1 m/s \simeq 0.71^o/oo$ S) and depth ($1 m/s \simeq 60 m$). The dependence on depth is linear, thus all "wiggles" in the profiles are caused by temperature and salinity changes (in the area under consideration, temperature effects dominate). Relative or differential salinity data can be obtained from a comparison of the sound speed and temperature profiles. Also, by comparing a spatial sequence of profiles or stations, major water motions, deep currents and information about mixing can be inferred.

The report is intended primarily as source material on microstructure and short-period variability of the waters involved.

Additional, earlier profiles obtained at sites approximating most stations of this report have been published in Volume II of the series (Piip, 1967).

PROCEDURE, INSTRUMENTATION, DATA PROCESSING

Normally two lowerings of the sensor package were undertaken at each station, yielding 4 consecutive profiles. During stations the ship was hove to. Depth, sound speed and temperature were measured with high-quality FM-output sensors. The sensor outputs, after suitable frequency division and filtering to eliminate frequency band overlaps and interchannel interference, were impressed on a very low distortion cable driver summing amplifier and transmitted to the recording position on the ship. Each of the submerged sensors was fed by its own Zener-stabilized power supply, all these from a constant-current supply incorporated in the central recording system in the ship's lab. Power went down and signals came up on the same single-conductor armored suspension cable.

Sound speed was measured with two independent velocimeters side-by-side, using different pairs from 4 available instruments in successive stations in order to improve reliability and to enable us to identify malfunctioning units, if any. Depth and temperature were measured with single instruments.

Topside, the multiplex signal on the cable was separated into its 4 component channels for recording. Two recording systems were normally used: for a quick, but not very accurate look, a two-pen XY recorder traced out sound speed and temperature versus depth plots while measurements were going on. For higher accuracy and later data processing, the 4 sensor output frequencies were quadrupled in a string of push-push doublers, counted for a second each and printed out on paper tape in a depth - velocimeter 1 - depth - velocimeter 2 - depth - temperature sequence. Recording was continuous during profiling, thus with a winch speed of about a meter per second digital readings for each channel were obtained every few meters in depth. Later on, in processing, a depth equal to the mean of the before-and-after values was assigned to each sound speed and temperature reading.

The final data processing was done on the LDGO IBM 1130 computer, yielding numerical printouts of data and machine-drawn sound speed and temperature profiles. These profiles, after inspection, validation, and tracing, form the basis of the figures in the report.

ACCURACY, CORRECTIONS TO THE PLOTS

The sound speeds in the graphs pertain to a velocimeter standardized for + 10°C. For other ambient temperatures, the readings in the plots have to be corrected for sound path expansion effects:

True sound speed = V_i + Correction

Correction = $1.46 \cdot 10^{-5}$ (T - 10) V_i

where T: ambient temperature, ^{o}C

and V_i: indicated sound speed

T, ^{o}C	Correction, m/s
30	+ 0.44
25	+ 0.33
20	+ 0.22
15	+ 0.11
10	+ 0.00
5	- 0.11
0	- 0.22

Depths are true, corrected values.

Conservative estimates of the quality of our data are as follows:

	Total uncertainty, absolute	Reproducibility, resolution
Sound speed	± 0.15 m/s	± 0.10 m/s
Temperature	± 0.05^{o}C	± 0.03^{o}C
Depth	± 5m ± $\frac{1}{2}$% $\leqslant$ ± 10m	± 2.5m ± $\frac{1}{4}$% $\leqslant$ ± 5m

The sound speed uncertainties are relative to the standard used in laboratory calibration of our velocimeters (Greenspan & Tschiegg, 1957). These tables were used as published, although it is generally accepted they are too high by about 0.3 m/s (C. E. Tschiegg, NBS, 1966, personal communication).

ORGANIZATION OF PLOTS

Figure 1 is a chart of our stations.

There are three figures for each station: 1) the individual, consecutive sound speed profiles, 2) the individual, consecutive temperature profiles, and 3) sound speed and temperature profile envelopes, showing the total spread of either quantity over the duration of the station.

The individual profiles have been spaced by 5 m/s, or 2°C to improve legibility. Each profile carries marks at round sound speed or temperature values, e.g. 1495, 1500, 1505 m/s etc.; or 5, 10, 15°C, etc.

The small horizontal ticks on the sound speed profiles are 10-minute time marks: the times and depths for each tick are listed in the Appendix "Timing of Profiles".

Temperature and sound speed profile envelopes are given in the same figure: temperature at left, sound speed at right.

All profiles have been reproduced on a uniform scale: 100m depth = 0.2 inches; 1 m/s = 0.1 inches; 1°C = 0.2 inches. An easy way to read the profiles is to prepare a transparent overlay of 10 x 10 to the inch graph paper.

RESULTS

It should be kept in mind that the oceanic structure is quite variable in all its aspects, and short-time fluctuations often can reach nearly the same order of magnitude as the long-time or seasonal changes. Long-time changes are really changes in the mean values, on which the rapid fluctuations are superimposed.

Therefore, our profiles, results and interpretations should not be construed as being valid in all detail for any time or season. They apply for a certain time, the time of our stations at each site, but can be expected to describe a typical situation or conditions from which considerable departures in detail are possible.

I. ANEGADA (Stations 120-126)

The situation in the Anegada Passage and Virgin Islands region turns out to be quite straightforward. The waters can best be described as intermediate between the Atlantic (Station 120, over the Puerto Rico Trench) and the Caribbean (Station 126, south of St. Croix).

(In order to make it easier for the reader to visualize the conditions and follow our reasoning, mean values of the Atlantic and Caribbean profiles have been superimposed on the profile envelopes of Stations 121-125, Figs. 41-45: Atlantic dashed, Caribbean dotted).

The surface mixing layer in the Caribbean is a little warmer than in the Atlantic. The pronounced temperature maximum at 30-50m depth, which causes an acoustic duct at the surface, is present in all stations from the Atlantic to between St. Thomas and St. Croix, but is absent in the Caribbean proper. Station 120 has an interesting pair of thin inversions in the middle of the near-surface mixing layer.

Over the Puerto Rico Trench we still find strong indications of the 18°C Sargasso Sea Water. Weaker traces of this can be found in all stations in the passage. They are quite prominent to the NE and N of the Atlantic side of the Passage (Stations 121,123), weak to the NW (Station 122); further south into the passage (Stations 124, 125) the only remainder of the Sargasso Sea waters is a zone of somewhat greater stratification and variability at the depth of the 17-18°C isotherms (2-300m), indicating patchy mixing.

Below the depth of 17°C, about 300m, the Caribbean intermediate water is consistently colder (about 1.5°C in the main thermocline) than the Atlantic to a depth of 1550m, under which the Caribbean becomes warmer again; at 1200m depth the Caribbean deep water becomes practically isothermal, while in the Atlantic temperature is still decreasing noticeably with depth. Because of the lower temperature at the lower knee of the thermocline in the Caribbean, the minimum sound speed is roughly 3 m/s lower than in the Atlantic, and the sound channel axis about 100m deeper.

At Station 121, NE of the passage, two prominent temperature inversions occur inside the thermocline at 500 and 700m depth. They are true inversions in the first profiles of the station, turning into square steps towards the end of the station. These square steps (thin isothermal layers) are still quite clear at Station 123, north of the approximate middle of the passage, but have disappeared NW of the passage, at Station 122. These layers reach well into the center of the passage, where they appear at 450 and 650m depth in Station 125.

The Caribbean and Atlantic sound speed profiles intersect at about 1610m, roughly 50 meters deeper than the temperatures. This means the Atlantic waters at this depth are about 1/3°/oo higher in salinity. All over the depth range, from the bottom of the surface mixing layer until the profiles intersect at sill depth near 1.5km, the temperature and sound speed profiles of all our stations in the passage lie between the Caribbean and Atlantic ones; except at depths between 850-1050m, where they touch and match the Atlantic ones. Only one conclusion is possible: there is an inflow of unmixed Atlantic water into the Caribbean at this depth. Rather uniform mixing of the Atlantic and Caribbean waters occurs both above and under this pure Atlantic jet, mixing which is smooth and uniform probably because of small-scale turbulence caused by the relatively near slopes at the edges of the passage.

A comparison of Stations 124 (mid-passage), 125 (between St. Thomas- St. Croix) and 126 (typical Caribbean) shows this deep Atlantic influx hugs the north and west sides of the passage and turns west (to the right) between St. Thomas and St. Croix, none of it reaching directly south of the passage.

At Station 124 our profiles break sharply away from the "Atlantic" at around 950m and rapidly approach the "Caribbean", which they meet and marry at roughly 1300m depth: there is an increasingly large proportion of Caribbean water in the mixture between 950 and 1300m.

At Station 125 there is no sharp breakaway in our profiles; they look very similar to those north of the passage (Stations 121, 122, 123). Our profiles remain snugly between the Atlantic and Caribbean ones until 1.5km depth is reached, after which they tend to follow the Atlantic closer than the Caribbean pattern: a large proportion of Atlantic water passing westwards.

II. THE ATLANTIC "FAR" STATIONS (Stations 132, 133, 134, 139, 140)

These 5 stations, more-or-less on a straight line parallel to the Lesser Antilles, have been included to show the gradual change of sound speed and temperature structures in the reasonably open Atlantic from the typical Sargasso Sea (Station 132) to just SE of Barbados (Station 139). Over these latitudes the Atlantic shows great changes (cf. Fig. 47). In general, the waters are quite variable and strongly stratified within a few hundred miles of the Antillean islands. Nevertheless, the mean of the profiles at each station is normally very close to what one can expect in the open sea several hundred additional miles to the east. Changes in the Caribbean between Anegada (Station 126) and Martinique, (e.g., Station 142) are minor compared to what happens in the Atlantic over the same range (cf. Fig. 53).

In moving south these 10° in latitude from 22°N, the following major changes occur in the Atlantic: The 18°C Sargasso Sea water disappears somewhere around 19°N - at Station 133, 18°N, hardly anything remains of it. The kinks in the thermocline and sound speed profiles corresponding to 18°C straighten out. The thermocline joins the near-surface mixing layer smoothly and gradually rises as one goes southwards. The 10°C isotherm rises from 750m in the Sargasso Sea to 400m near Barbados, 15°C from 480 to 230m. Below 1300m, temperatures remain unchanged. Surface waters get only slightly warmer in the south.

Because of the general cooling at depths between 100-1200m, the sound speed minimum occurs at shallower depths towards the south and the axis speed gets slower, from 1492 m/s at 12-1300m in the Sargasso Sea to 1486 m/s at 800m depth near Barbados. In the process the sound channel gets narrower and more pointed in shape. A shallow acoustic duct in the surface mixing layer occurs at all stations, except 133.

IIa. STATION 134: A COLD WATER CELL ABOVE 600m

The thermocline and sound speed profiles at this station, 120 miles E of the St. Lucia-Martinique channel and 120 miles NNW of Barbados, are clearly pathological in the topmost 600 meters. The normal shape of both kinds of profiles at this location is quite smooth, without the sharp step at 600m depth found at Station 134.

The normal profiles can be approximated very closely by joining the sharp corner of the step, at 600m, to the bottom of the surface layer, at roughly 100m, with a straight line.

We have here an errant cell of water, originationg at a different region of the ocean, which has been transported unmixed over long distances by a current.

This cell of cold water reaches from a depth of 600m, where it has a temperature of 9°C and a very sharp, unmixed bottom boundary, to 160m. The upper portion of the cell gradually merges into the surface layer. At 400m depth it has decreased the sea temperature by 5°C, from a norm near 15°C to 10°C; and lifted the 12° and 13° isotherms by 200m, from 450 to 250m and 400 to 200m.

Without water samples and chemistry we cannot locate the source of this water unequivocally. Its temperature and sound speed structure is similar to near-equatorial waters in the Mid-Atlantic; and to Eastern Atlantic waters of the Cape Verde Basin, at the other side of the Mid-Atlantic Ridge. The latter source seems more probable, the cell having been brought west by the North Equatorial Current without an appreciable change of its geographical latitude.

This type of errant cell cannot be very rare in the Barbados region. (Did BOMEX find anything of this sort?) This is borne out by our previous Station 29 (30 April 1964) in the St. Lucia Channel, described in Volume II of this series. On that occasion the whole passage was filled by waters very similar to those of Station 134, reaching from the Atlantic into the Caribbean, a distance of at least 30 miles. The main difference at that time was that the knee was a little deeper (650-700m) and colder (7°C), and cooling at intermediate depths was not quite as drastic as in Station 134.

III. THE MARTINIQUE PASSAGES (Stations 141-147)

The situation at these two passages is not as clear as at Anegada. Being in the middle of the Antillean island arc, surrounded both north and south by numerous shallow passages between the Atlantic and Caribbean; being right in the path of the trade winds and windriven surface currents, close to the deeper currents paralleling the island arc and in a general area where several different water types meet, the region between the islands and a few hundred miles to the east is characterized by very confused and highly variable waters. In addition, during the time of our stations the region was somewhat influenced by the cold water mass observed in Station 134, a month earlier: in several of our stations, particularly those east of the passages, kinks in the profiles and extreme variability occur at depths which suggest meeting and mixing of the normally ambient waters with those of the cold cell.

Again, the Caribbean side is much simpler than the Atlantic. Compared to Station 126 (Anegada, November) the thermocline between 150-600m is at shallower depth, typical of the more southerly location (cf. Fig. 53). Sound speeds in the same interval are higher, by 10-12 m/s at depths between 300-500m. The sound channel proper is slightly deeper, at 1000m, but does not differ in minimum speed. It is interesting to note that the prominent "wiggles" in the profiles between 700-1000m depths occur in nearly identical form both around Anegada and Martinique. Below 1000m, there is no real difference between the two regions.

IIIa. ST. LUCIA-MARTINIQUE CHANNEL (Stations 141-144)

Approaching this passage from the SE we find a sharp transition between Stations 140 and 141. At Station 140, a zone of extreme variability occurs at depths 300-700m, the profiles gradually changing shape from something rather similar to what was observed at Station 134 to a form more typical of the region; i.e. Station 140 must have been at the edge of the cold water mass of 134 which seemingly had not progressed much westward during the 30 days between these two stations. At Station 141* there is a variable, disturbed zone at the same depths, the whole region between 300 and 900m being approximately a degree warmer, and a few m/s higher in sound speed than at 140. At 850m depth a patchy warm, high sound speed layer can be observed--the water in this 60m thick layer, prominent in profile 2, is much more typical of the Caribbean than of the Atlantic. It occurs at just the same depth and place where we have observed similar warm, thin layers during our previous visits to the passage, in 1963 and 1964 (Volumes I and II of this series: Piip 1966, 1967). At that time we described it as a deep jetlike easterly countercurrent, presumably patchy in summertime. Our postulate still holds.

At the sill, Station 143, traces of "cold 134 water" are found in the region between 300-600m depths. This strongly stratified, rapidly variable region is colder and has a lower sound speed than either the Atlantic (e.g., Station 141) or the Caribbean (Stations 142, 144) at the same depths. Between 650 and 800m, at the same depths as the postulated warm, easterly countercurrent of Station 141, both the temperature and sound speeds are higher than in the open seas on either side of the channel. Again, this is a rapidly variable, patchy, and stratified region as evidenced by the large changes from one profile to the next.

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*The lower part of the temperature profiles of Station 141, dashed in the figures, has been reconstructed from the quick-look shipboard XY plots. They should be good to $\pm$ 0.1°C. At this station a small pinhole leak developed in a connecting lead between the thermometer and the multiplexer, attenuating the thermometer signal too much for reliable frequency counting, but not enough to impair operation of the FM discriminator feeding the XY plotter.

IIIb. DOMINICA PASSAGE (Stations 145-147)

At first glance, the profiles from our three stations around Dominica Passage look deceivingly similar. They all show pronounced stratification and zones of rapid and strong variability at depths between 500-1000m, with apparent maximum activity around the inversion layers at around 600m. Stations 145 and 146, about a dozen miles apart, one at the Caribbean entrance to the passage, the other in the middle of it, really are identical within variability limits. Compared to Stations 142 and 144 near the southern end of Martinique, they are considerably more stratified at 500-1000m depths, the inversions are much more intense; except between roughly 650-800m, which seem to be less confused towards the north of the island.

Going 40 miles NE from the passage, to Station 147, takes us out from the practically Caribbean water in the passage into the typical Atlantic: temperatures and sound speeds between 400-1400m increase by half a degree or a couple of m/s; the slight bulge to the right appears in sound speed profiles just below 1000m depth; the deep waters under 1500m grow colder with increasing depth. An interesting feature of Station 147 is the occurence of cold water (a patch?) at the very bottom of profiles 3 and 4.

The shallow inversion layers around 250m in the passage have disappeared at Station 147, and the main thermocline is quite smooth down to 3-400m.

x - x - x

A memorable part of this cruise of SIR HORACE was the run between Stations 144 and 145, west of Martinique. Off St. Pierre, dominated by the looming bulk of Mt. Pelee, we ran into the biggest school of dolphin (the cetacean kind) anybody on board had ever seen: hundreds of them playing, the sea aboil in a circle half a mile in diameter.

IV. ANEGADA versus MARTINIQUE

The main difference between the two systems of passages seems to be that at Anegada a distinct layer of Atlantic water can be followed to quite a distance into the Caribbean, near the Northwestern side of the passage.

Around Martinique, the Caribbean dominates nearly to the eastern entrances to the passages, except at a confused region at 500-1000m depths.

ACKNOWLEDGEMENTS

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APPENDIX
Timing of Profiles

Profile	D(m)	GMT	Profile	D(m)	GMT	Profile	D(m)	GMT	Profile	D(m)	GMT
120/1	10	1303	121/3	1187	0310	123/1	10	1509	124/4	1427	0428
	133	1310		1459	0320		18	1510		1395	0430
	426	1320		1750	0330		344	1520		1029	0440
	716	1330		2017	0340		673	1530		714	0450
	1056	1340		2059	0343		1021	1540		364	0500
	1389	1350	121/4	2016	0347		1388	1550		105	0510
	1712	1400		1963	0350		1736	1600		1	0515
	2016	1410		1668	0400		2005	1609			
120/2	2007	1420		1313	0410	123/2	2005	1616	125/1	1	0735
	1677	2430		897	0420		1906	1620		55	0740
	1281	1440		487	0430		1550	1630		324	0750
	889	1450		147	0440		1111	1640		639	0800
	489	1500		1	0445		593	1650		959	0810
	184	1510					57	1700		1253	0820
	1	1516	122/1	5	0827		1	1702		1533	0830
120/3	4	1530		105	0830	123/3	2	1705		1857	0840
	328	1540		395	0840		163	1710		1048	0847
	716	1550		707	0850		592	1720	125/2	2056	0850
	1087	1600		927	0900		1028	1730		1789	0900
	1443	1610		1145	0910		1330	1740		1456	0910
	1815	1620		1334	0920		1593	1750		1277	0920
	2008	1624		1507	0930		1821	1800		874	0930
120/4	2005	1630		1683	0940		2001	1810		354	0940
	1643	1640		1913	0950		2055	1812		1	0949
	1267	1650		2005	0954	123/4	2054	1816	125/3	0	0951
	857	1700	122/2	2007	1006		1940	1820		569	1000
	401	1710		1918	1010		1567	1830		839	1010
	1	1720		1660	1020		1142	1840		1295	1020
				1306	1030		650	1850		1712	1030
121/1	1	0002		875	1040		239	1900		2011	1038
	189	0010		496	1050		2	1906	125/4	2014	1041
	524	0020		93	1100					1755	1051
	827	0030		1	1103	124/1	2	0144		1334	1100
	1108	0040	122/3	1	1106		125	0150		921	1110
	1385	0050		88	1110		385	0200		557	1120
	1672	0100		378	1120		659	0210		141	1130
	1932	0110		698	1130		948	0220		1	1134
	2072	0116		989	1140		1248	0230			
121/2	2056	0120		1223	1150		1517	0238	126/1	1	2005
	1818	0130		1542	1200	124/2	1514	0242		159	2010
	1530	0140		1791	1210		1250	0250		564	2020
	1191	0150		2003	1217		877	0300		915	2030
	1004	0200	122/4	2003	1221		566	0310		1216	2040
	645	0210		1720	1230		253	0320		1653	2050
	208	0220		1359	1240		2	0328		2011	2058
	1	0225		940	1250	124/3	3	0332	126/2	2011	2100
121/3	1	0230		576	1300		167	0340		1761	2110
	205	0240		180	1310		407	0350		1404	2120
	517	0250		1	1318		652	0400		1032	2130
	851	0300					972	0410		799	2140
							1239	0420			
							1492	0425			

APPENDIX (Cont.)
Timing of Profiles

Profile	D(m)	GMT	Profile	D(m)	GMT	Profile	D(m)	GMT	Profile	D(m)	GMT
126/2	493	2150	133/2	2204	1748	134/3	621	0050	140/3	356	0530
	229	2200		1971	1800		835	0100		636	0540
	1	2208		1767	1810		1077	0110		896	0550
126/3	1	2213		1554	1820		1355	0120		1153	0600
	195	2220		1323	1830		1641	0130		1493	0610
	491	2230		1077	1840		1707	0132	140/4	1492	0622
	794	2240		793	1850	134/4	1712	0139		1212	0630
	1098	2250		458	1900		1702	0140		887	0640
	1401	2300		94	1910		1524	0150		651	0650
	1714	2310		4	1912		1309	0200		434	0700
	2036	2320	133/3	8	1916		1018	0210		232	0710
126/4	2054	2323		124	1920		747	0220		3	0720
	1944	2330		397	1930		514	0230			
	1758	2340		696	1940		220	0240	141/1	1	1040
	1557	2350		957	1950		14	0248		223	1050
	1240	2400		1206	2000					388	1100
	965	0010		1408	2010	139/1	2	0315		600	1110
	648	0020		1620	2020		66	0320		673	1120
	395	0030		1902	2030		277	0330		795	1130
	0	0033		2206	2039		464	0340		1010	1140
			133/4	2207	2045		672	0350		1268	1150
132/1	2	1443		2081	2050		971	0400		1608	1200
	119	1450		1823	2100		1365	0410		1684	1202
	479	1500		1545	2110		1589	0415	141/2	1629	1211
	848	1510		1235	2120	139/2	1582	0423		1329	1220
	1191	1520		873	2130		1376	0430		1004	1230
	1505	1530		465	2140		1012	0440		716	1240
	1800	1540		108	2150		878	0450		484	1250
	2090	1550		8	2156		427	0500		302	1300
	2210	1554					61	0510		46	1310
132/2	2209	1600	134/1	12	2129		1	0513		3	1312
	2017	1610		27	2130				141/3	3	1319
	1813	1620		258	2140	140/1	1	0247		15	1320
	1595	1630		509	2150		30	0250		276	1330
	1365	1640		780	2200		215	0300		521	1340
	1118	1650		1028	2210		467	0310		731	1350
	850	1700		1304	2220		786	0320		908	1400
	534	1710		1508	2227		1017	0330		1073	1410
	176	1720	134/2	1759	2252		1258	0340		1254	1420
	1	1727		1617	2300		1467	0350		1425	1430
				1440	2310		1493	0355		1599	1437
133/1	0	1634		1354	2320	140/2	1493	0402	141/4	1547	1445
	161	1640		1059	2330		1288	0410		1428	1450
	459	1650		854	2340		1005	0420		1139	1500
	755	1700		643	2350		755	0430		887	1510
	1088	1710		439	2400		530	0440		656	1520
	1441	1720		248	0010		423	0450			
	1776	1730		13	0019		193	0500	142/1	3	0101
	2071	1740	134/3	15	0024		2	0508		288	0110
	2203	1745		134	0030	140/3	3	0516		581	0120
133/2	2204	1748		371	0040		73	0520		870	0130

APPENDIX (Cont.)
Timing of Profiles

Profile	D(m)	GMT
142/1	1196	0140
	1523	0150
	1850	0200
	1963	0204
142/2	1958	2208
	1912	0210
	1666	0220
	1384	0230
	1077	0240
	706	0250
	357	0300
	2	0310
142/3	1	0313
	196	0320
	530	0330
	850	0340
	1197	0350
	1556	0400
	1883	0410
	1950	0412
142/4	1951	0416
	1876	0420
	1608	0430
	1316	0440
	940	0450
	533	0500
	173	0510
	1	0512
143/1	1	1020
	236	1030
	418	1040
	582	1050
	728	1100
	893	1110
	1071	1120
	1119	1122
143/2	1114	1125
	997	1130
	709	1140
	383	1150
	80	1200
	2	1203
143/3	1	1209
	23	1210
	242	1220
	454	1230
	664	1240
	906	1250

Profile	D(m)	GMT
143/3	1090	1300
	1104	1303
143/4	1097	1304
	981	1310
	831	1320
	674	1330
	507	1340
	304	1350
	2	1400
144/1	0	1521
	192	1530
	397	1540
	569	1550
	753	1600
	952	1610
	1118	1620
	1401	1630
	1699	1640
	1877	1647
144/2	1855	1649
	1844	1650
	1599	1700
	1371	1710
	1146	1720
	919	1730
	652	1740
	390	1750
	132	1800
	0	1804
145/1	1	2252
	134	2300
	400	2310
	648	2320
	865	2330
	1105	2340
	1362	2350
	1603	2400
	1845	0010
	1963	0015
145/2	1958	0018
	1918	0020
	1672	0030
	1427	0040
	1154	0050
	870	0100
	599	0110
	379	0120

Profile	D(m)	GMT
145/2	110	0130
	1	0135
145/3	1	0138
	37	0140
	237	0150
	463	0200
	744	0210
	1015	0220
	1284	0230
	1550	0240
	1831	0250
	2015	0255
145/4	2012	0259
	2005	0300
	1779	0310
	1529	0320
	1274	0330
	951	0340
	545	0350
	228	0400
	1	0407
146/1	2	0702
	57	0710
	391	0720
	676	0730
	943	0740
	1165	0750
	1428	0800
	1722	0810
	1857	0813
146/2	1853	0817
	1767	0820
	1489	0830
	1241	0840
	973	0850
	725	0900
	439	0910
	70	0920
	0	0926
146/3	0	0928
	52	0930
	357	0940
	662	0950
	970	1000
	1210	1010
	1538	1020
	1864	1027

Profile	D(m)	GMT
146/4	1864	1030
	1565	1040
	1216	1050
	842	1100
	478	1110
	175	1120
	0	1129
147/1	0	1702
	206	1710
	550	1720
	872	1730
	1159	1740
	1412	1750
	1643	1800
	1883	1810
	1956	1820
147/2	1953	1815
	1838	1820
	1532	1830
	1206	1840
	870	1850
	518	1900
	96	1910
	0	1912
147/3	0	1918
	8	1920
	313	1930
	558	1940
	796	1950
	1031	2000
	1405	2010
	1850	2020
	1953	2021
	1953	2026
	1900	2030
	1602	2040
	1259	2050
	900	2100
	485	2110
	59	2120
	0	2124

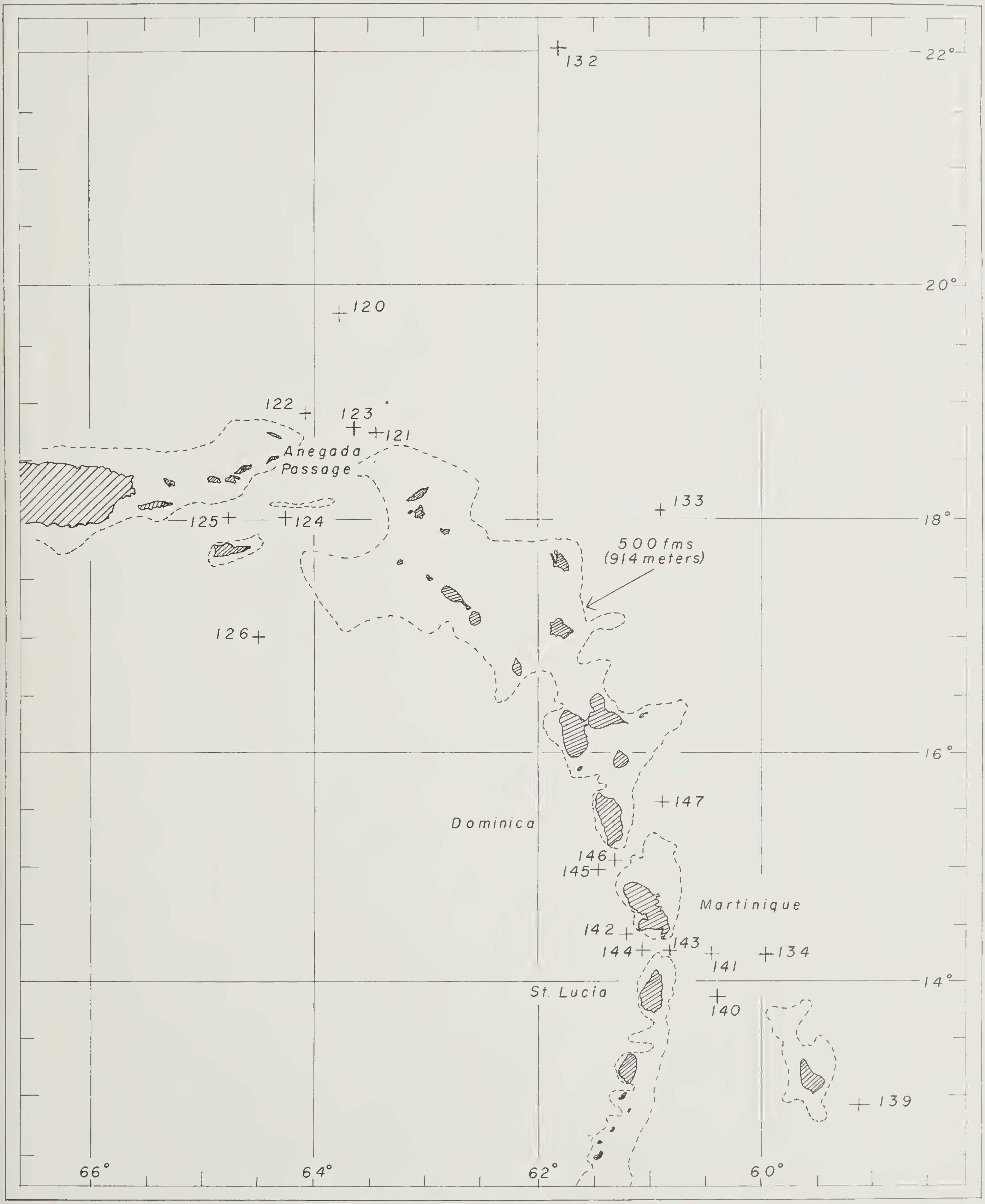


Fig. 1 - Chart of Stations

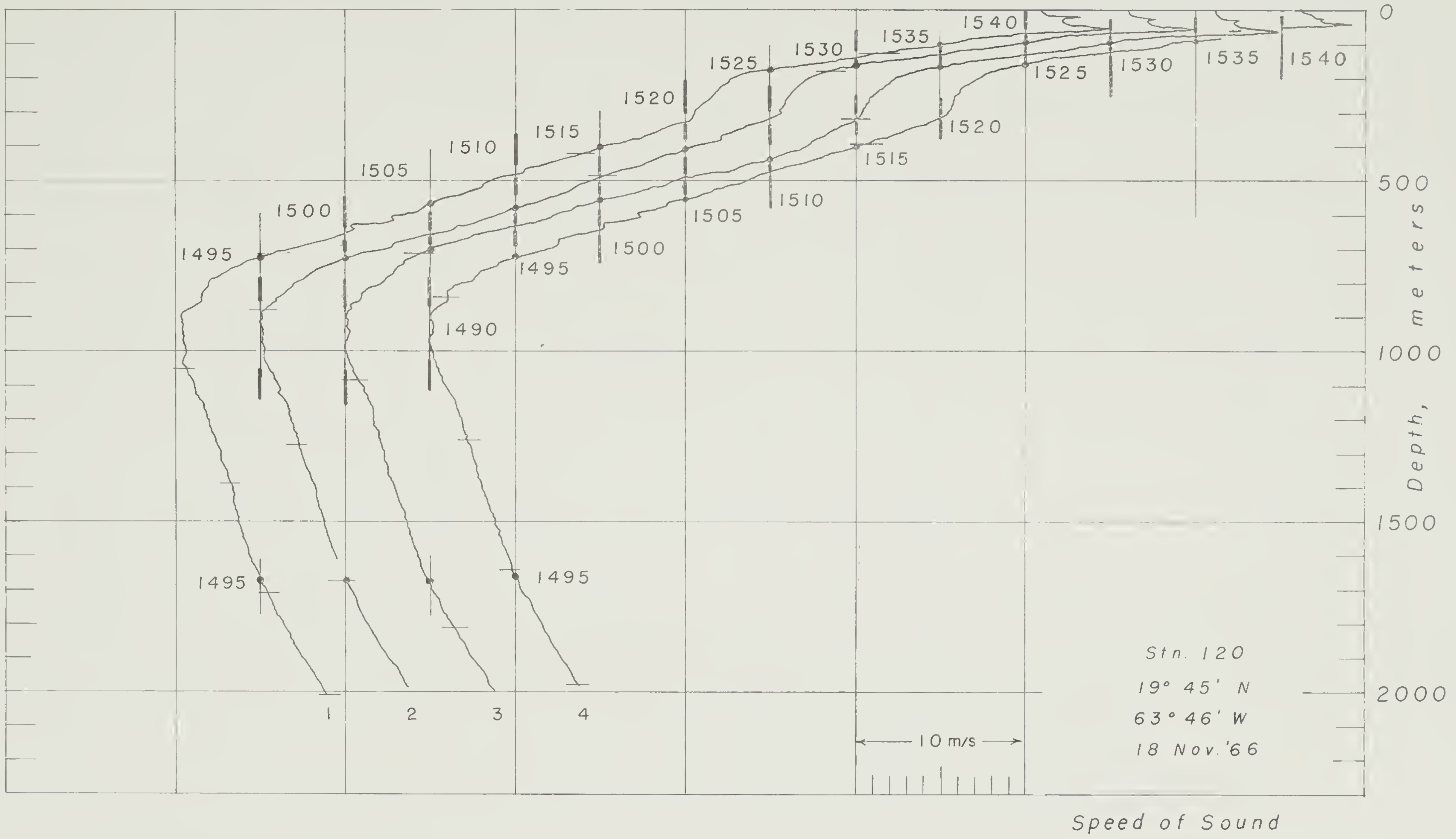


Fig. 2 Sound Speeds - Station 120

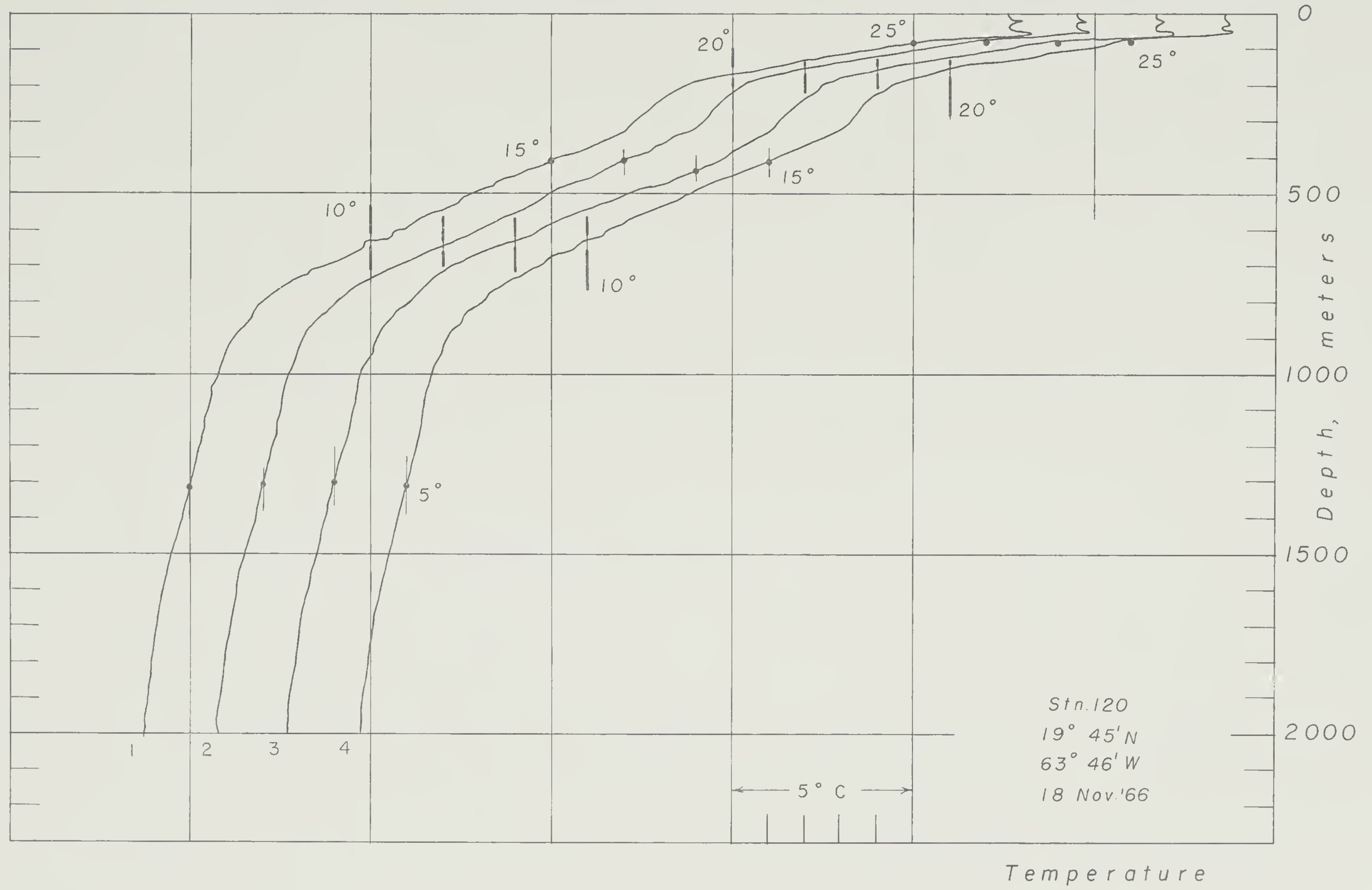


Fig. 3 Temperature - Station 120

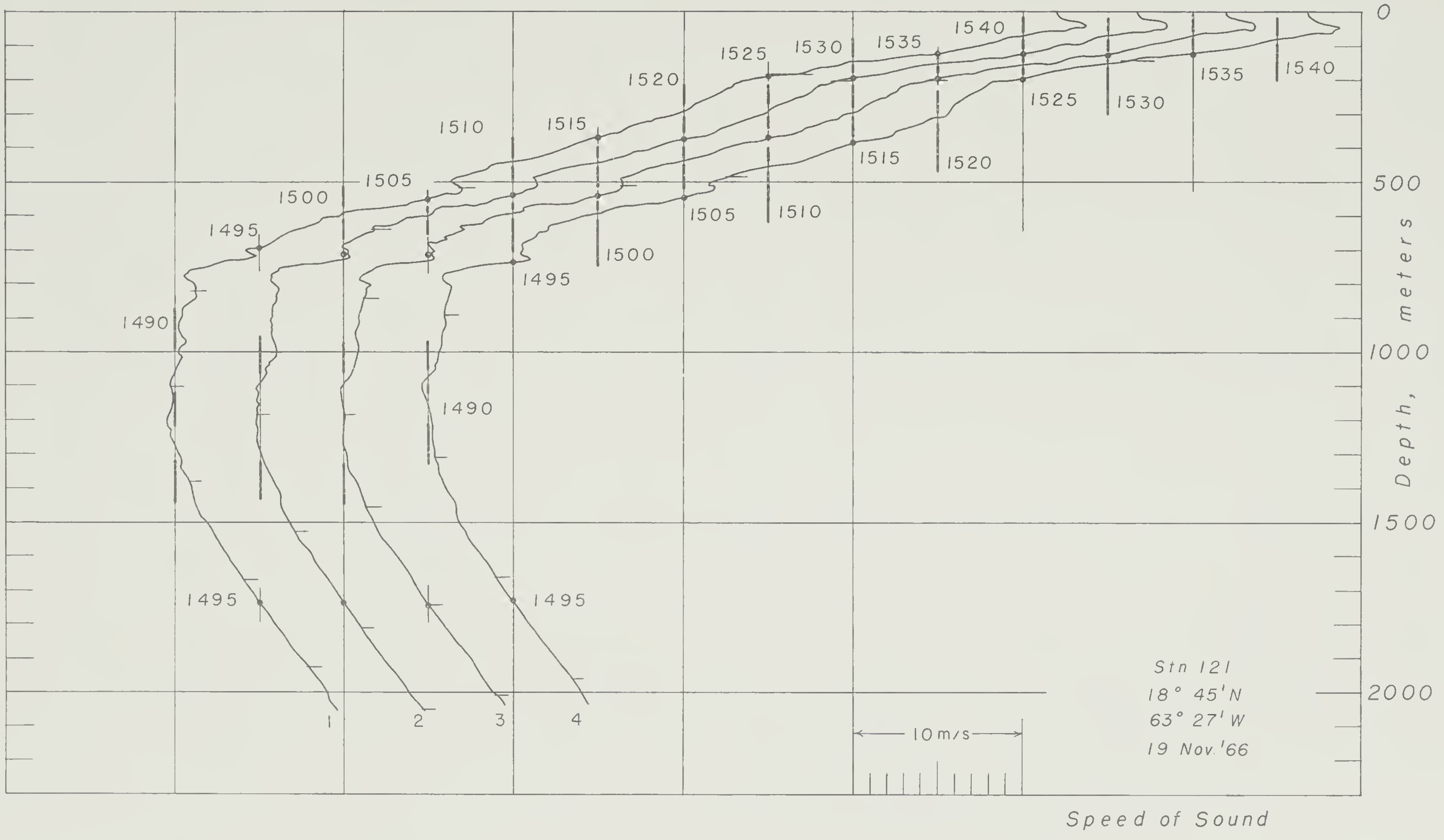


Fig. 4 Sound Speeds - Station 121

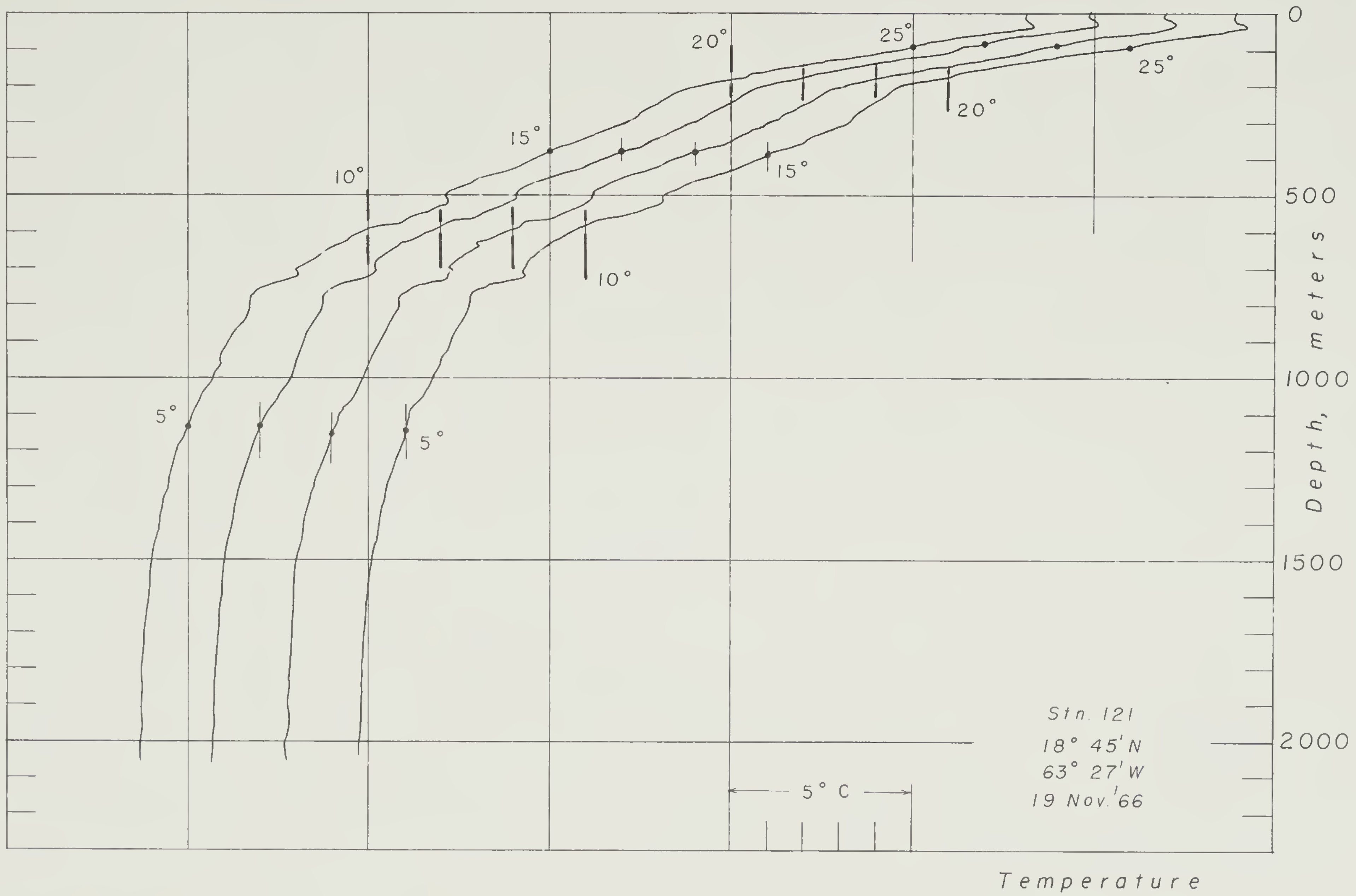


Fig. 5 Temperature-Station 121

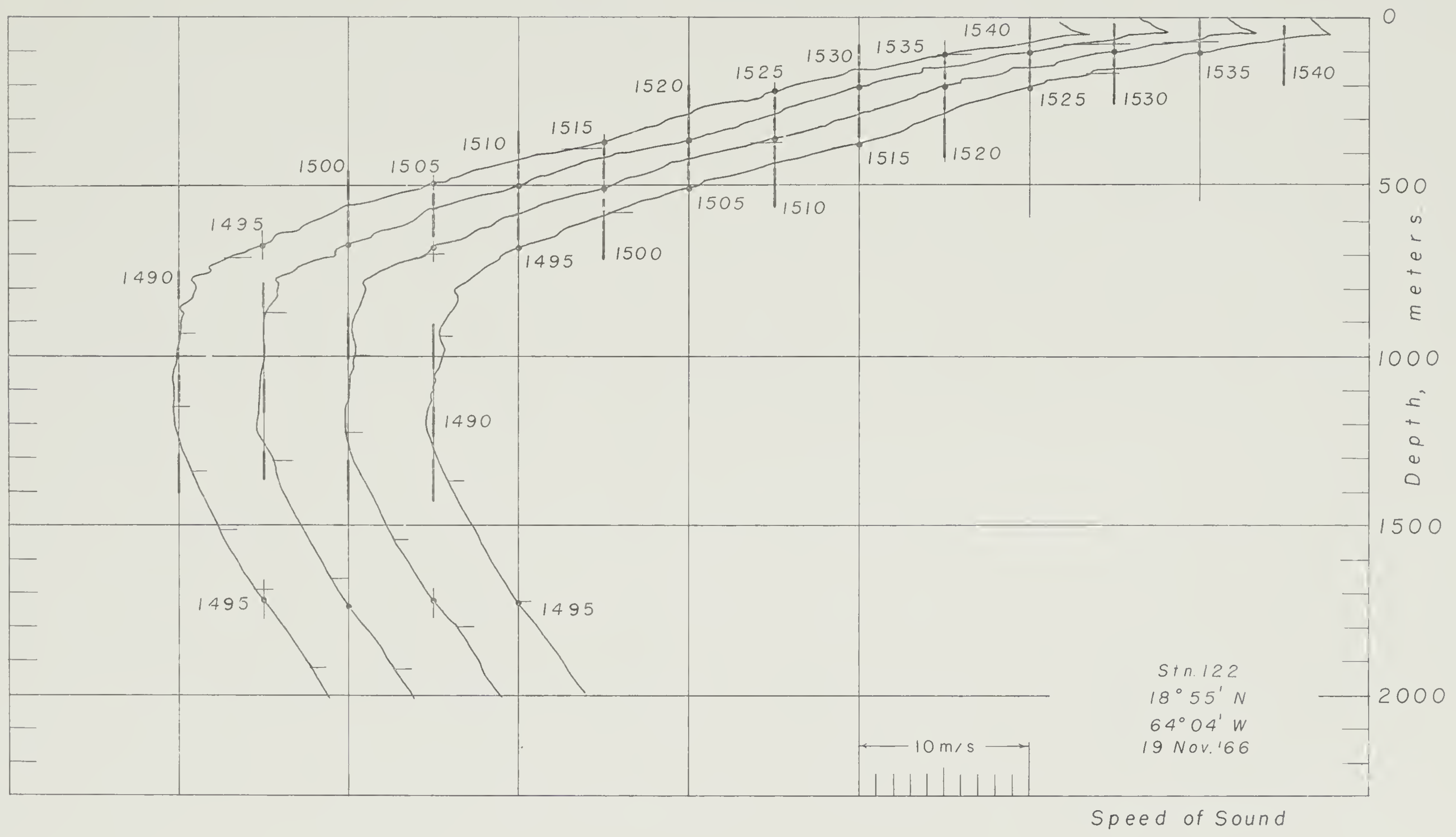


Fig. 6 Sound Speeds - Station 122

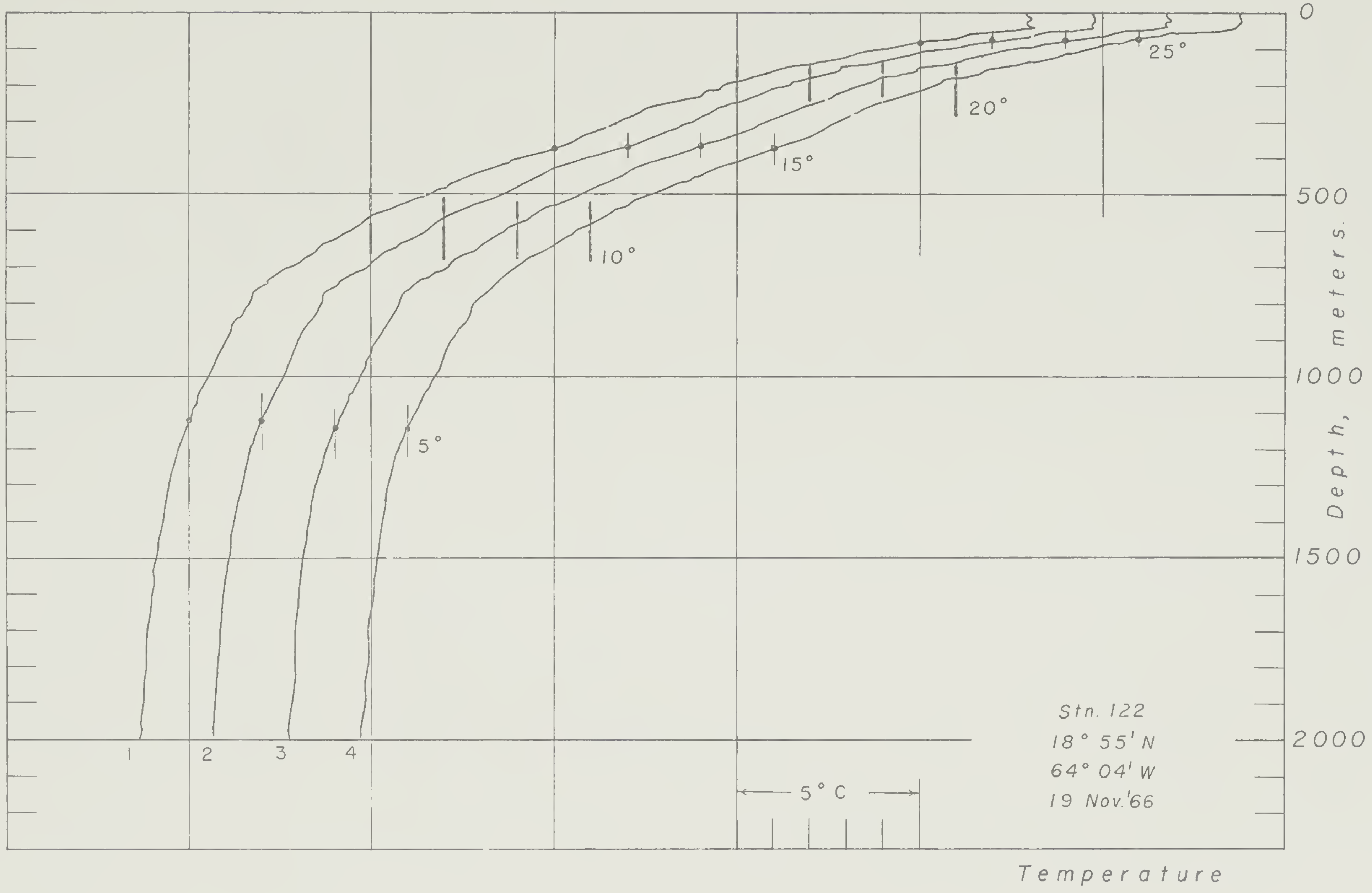


Fig. 7 Temperature - Station 122

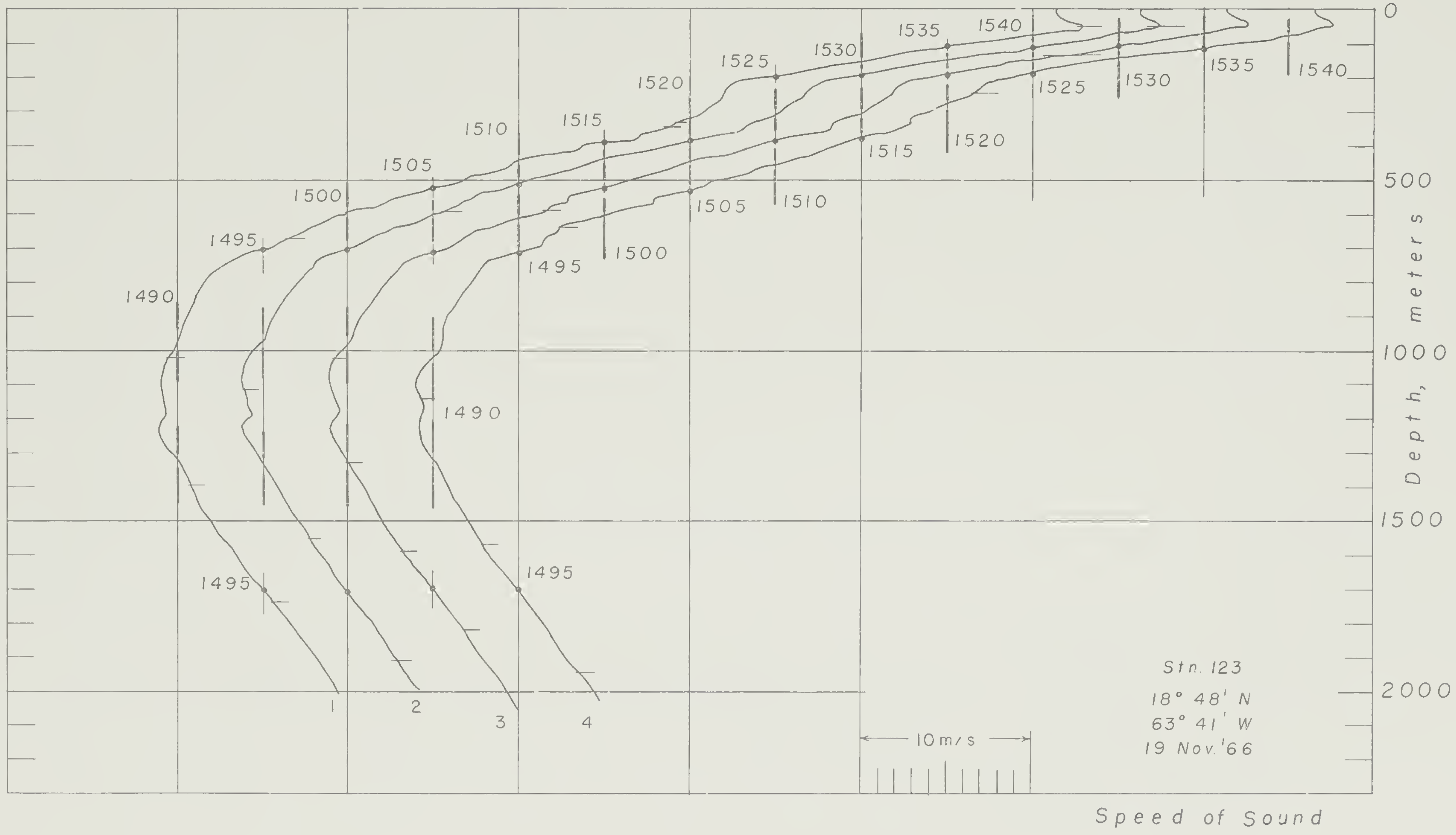


Fig. 8 Sound Speeds - Station 123

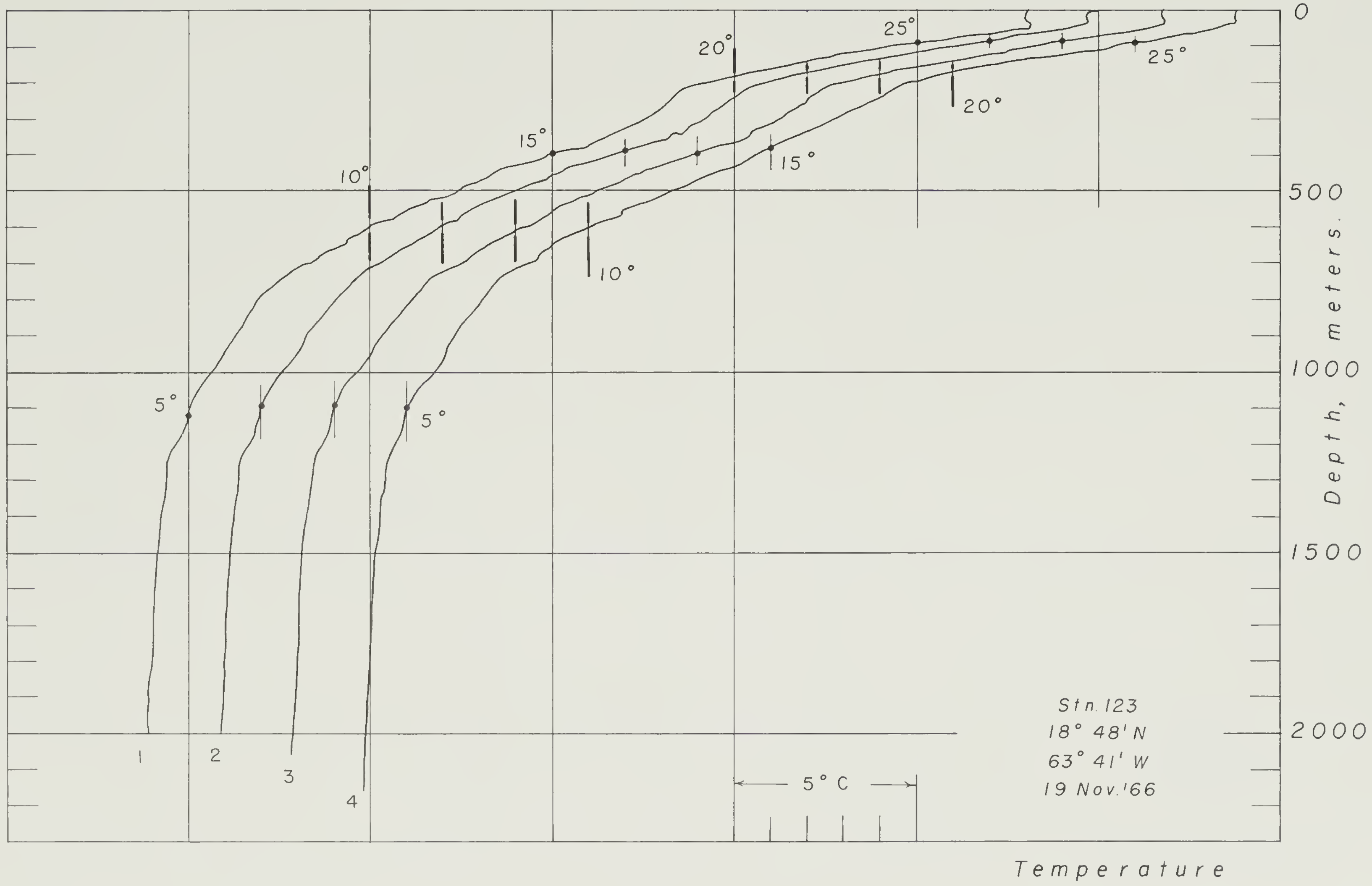


Fig. 9 Temperature - Station 123

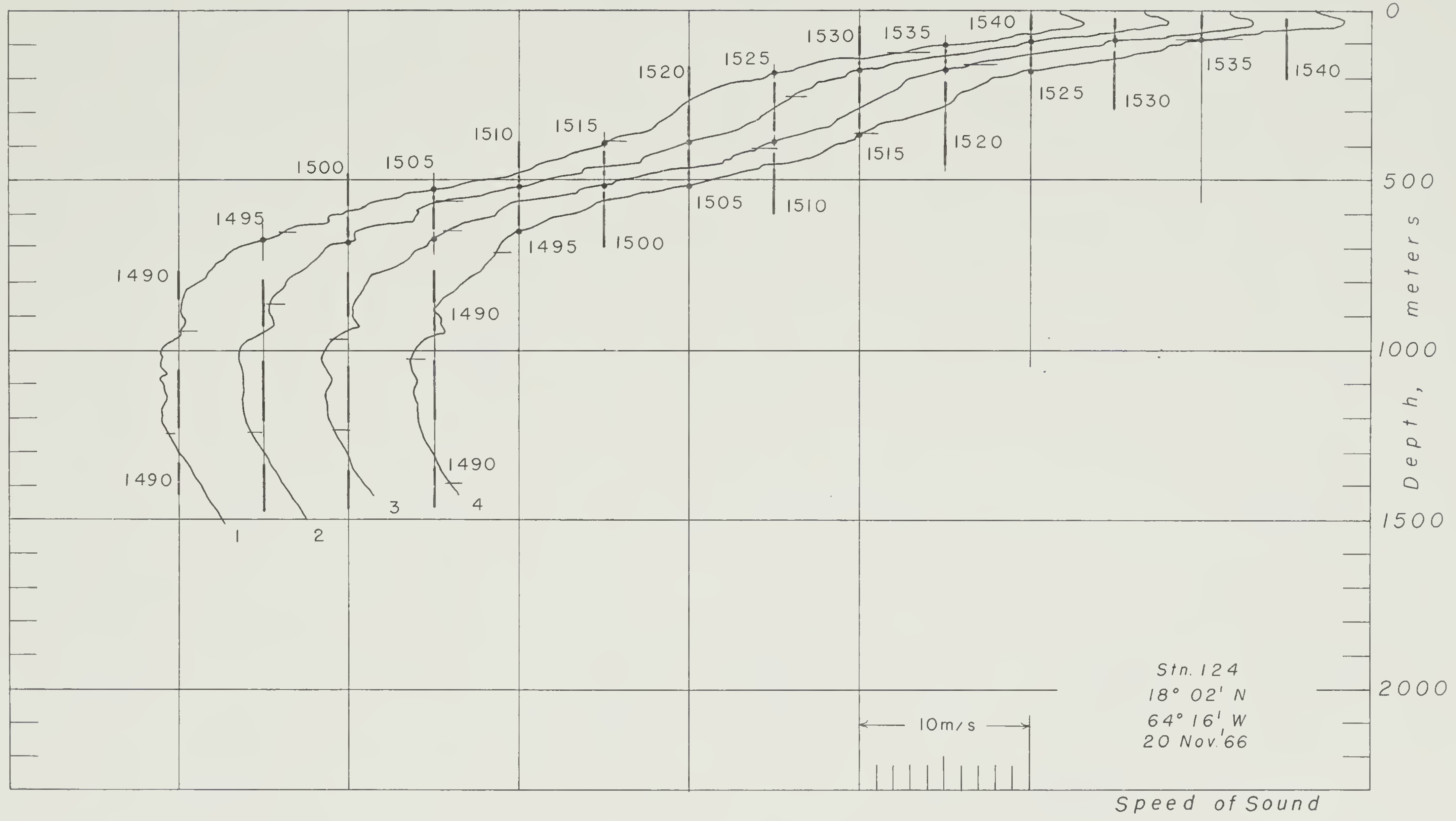


Fig. 10 Sound Speeds - Station 124

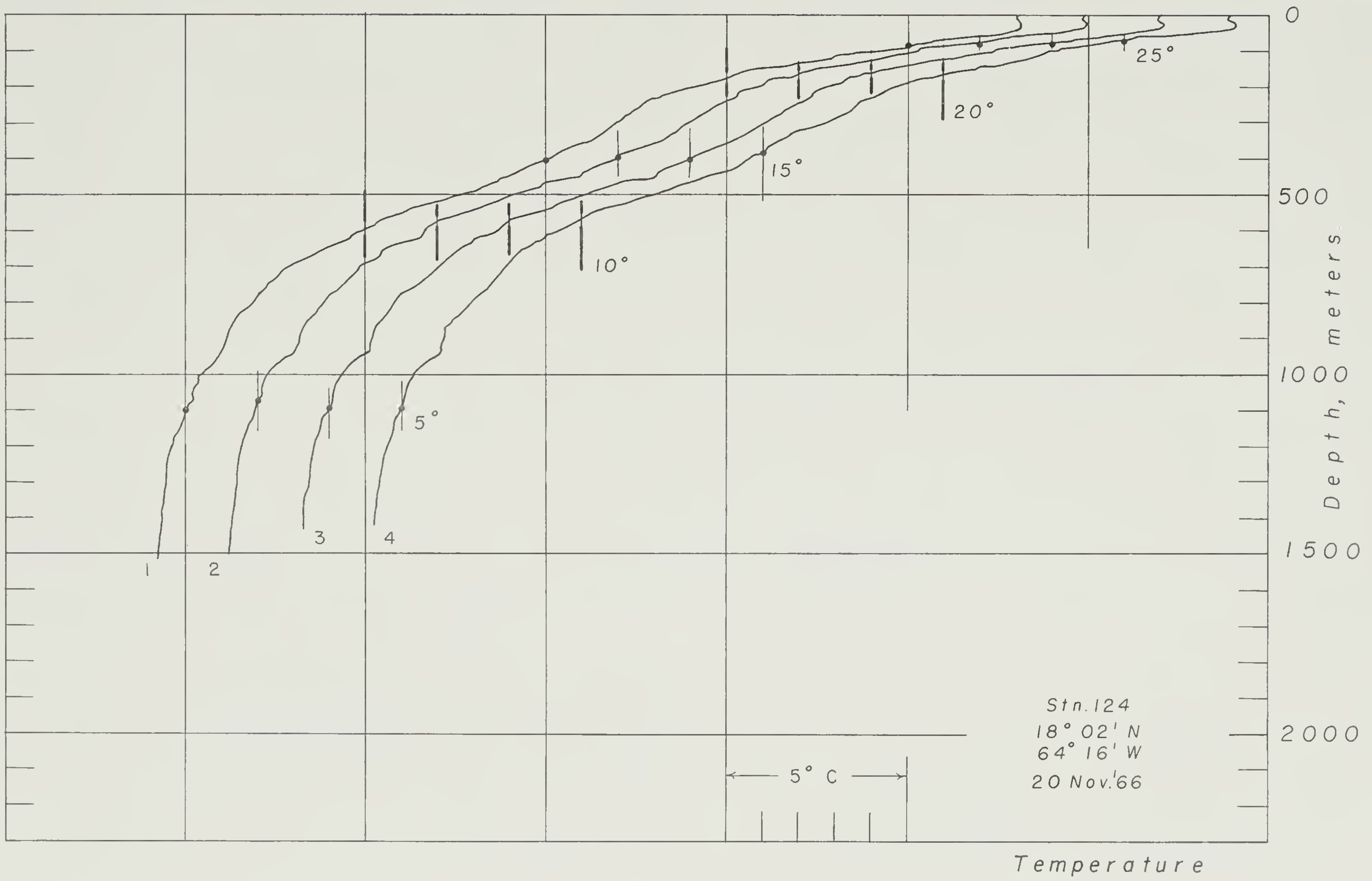


Fig. II Temperature - Station 124

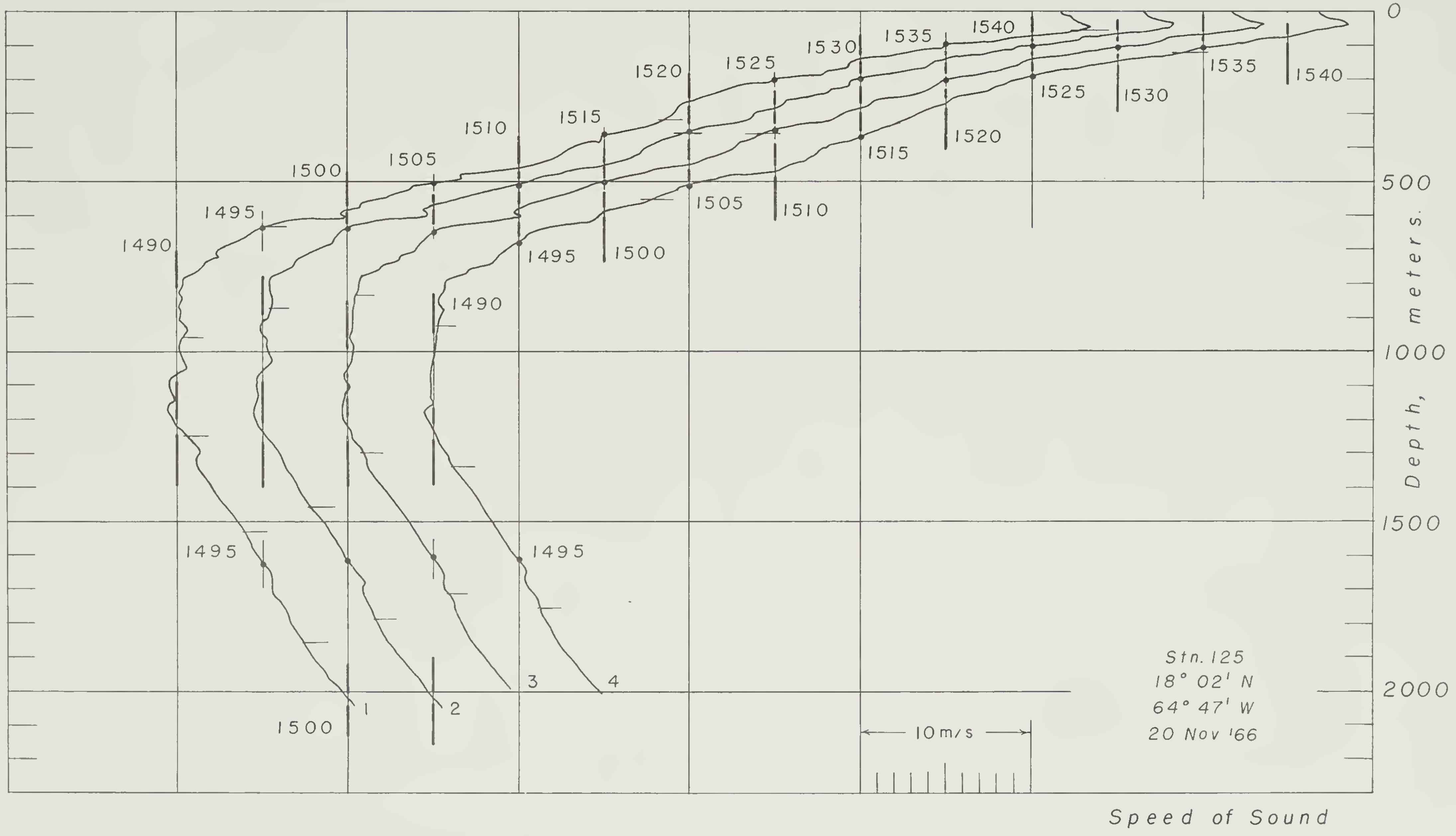


Fig. 12 Sound Speeds - Station 125

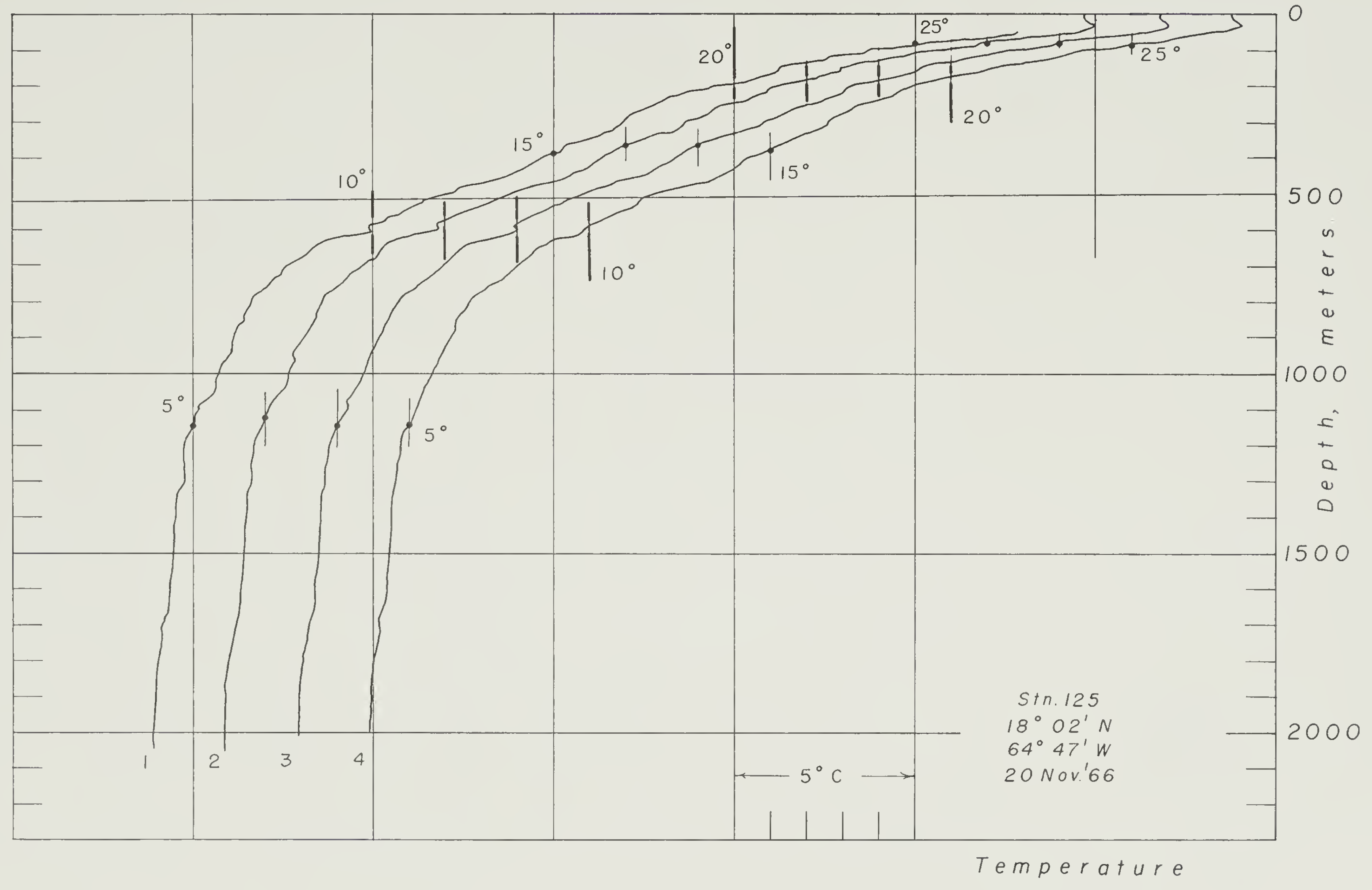


Fig. 13 Temperature - Station 125

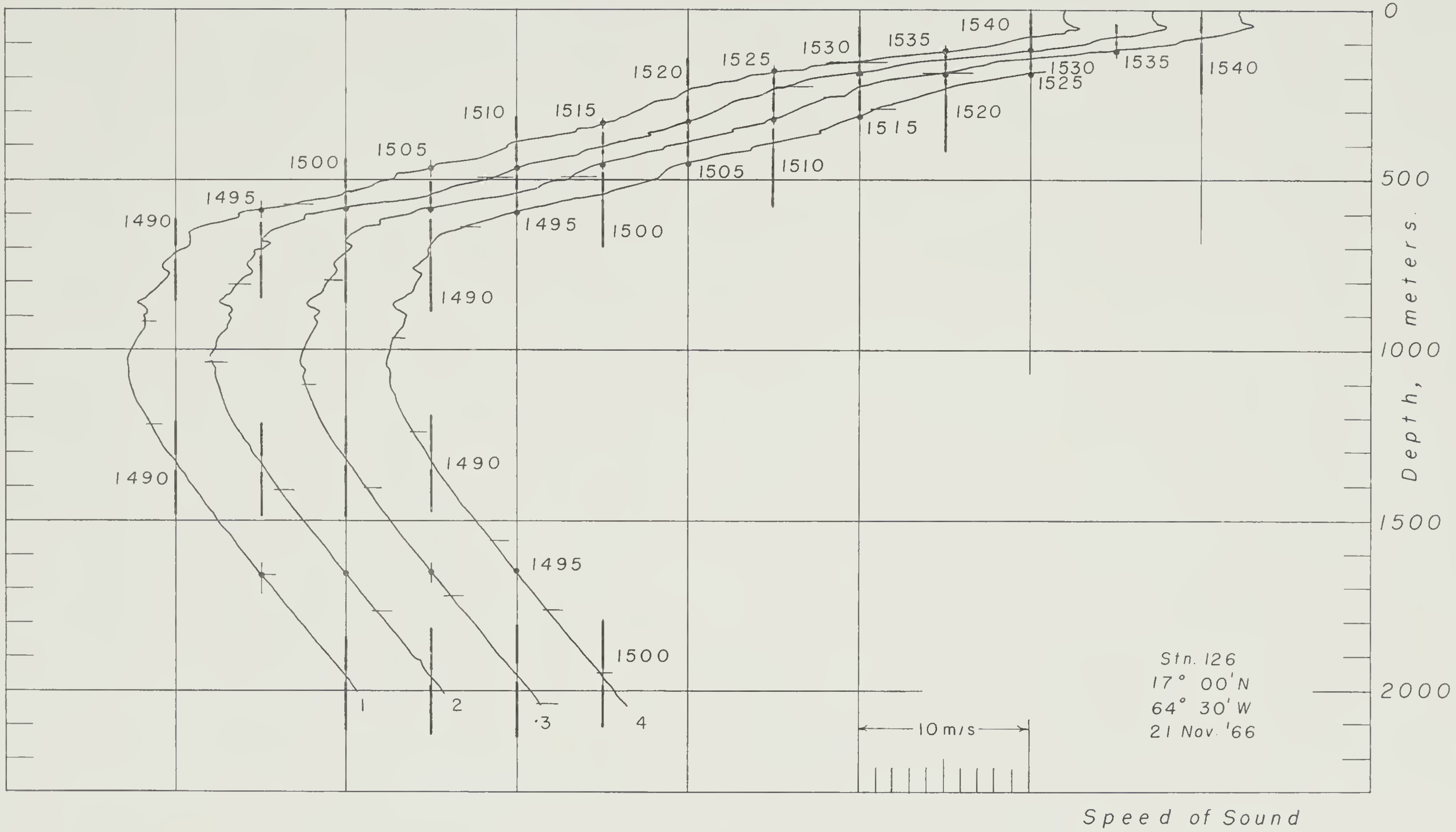


Fig. 14 Sound Speeds - Station 126

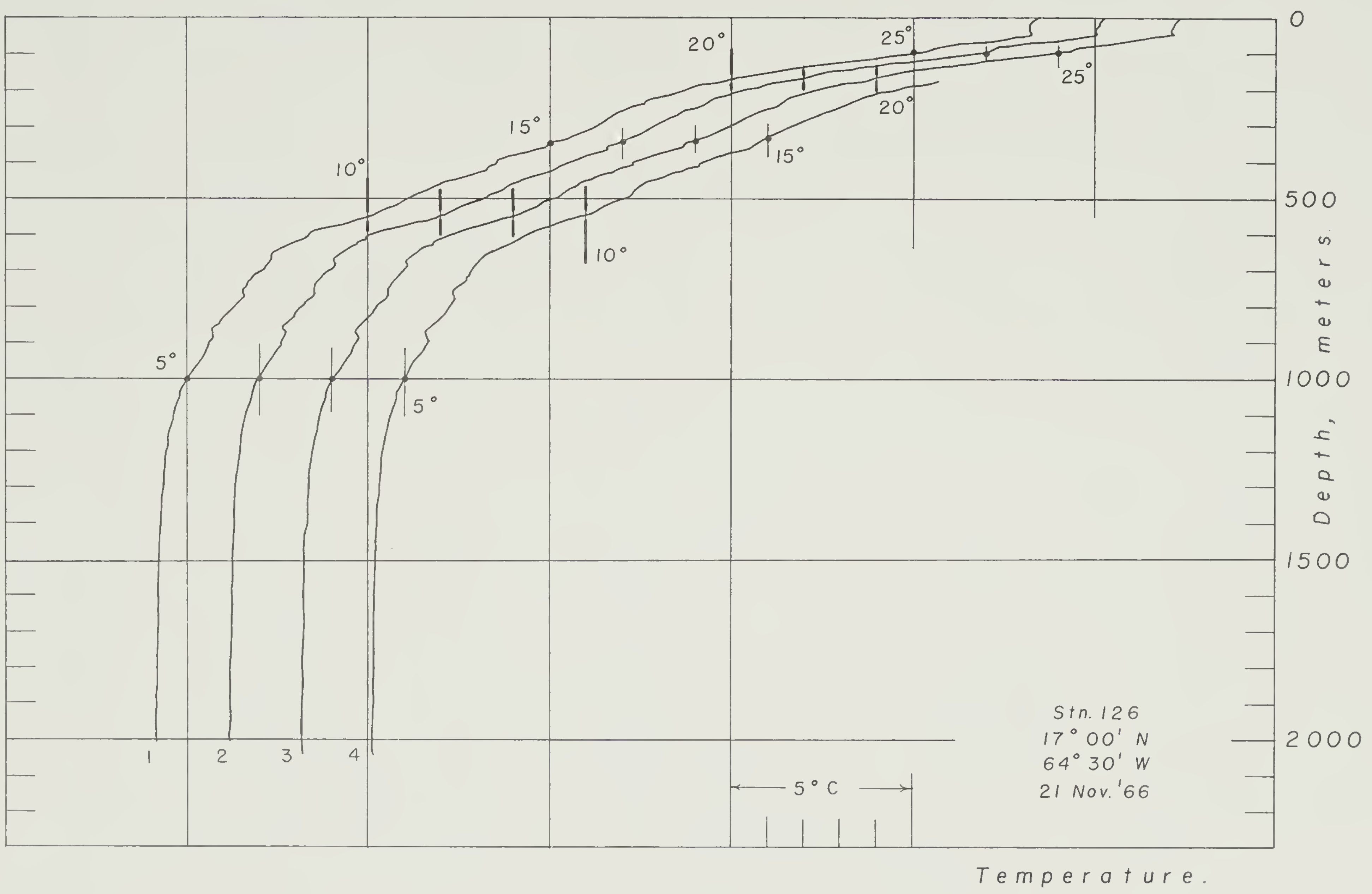


Fig. 15 Temperature - Station 126

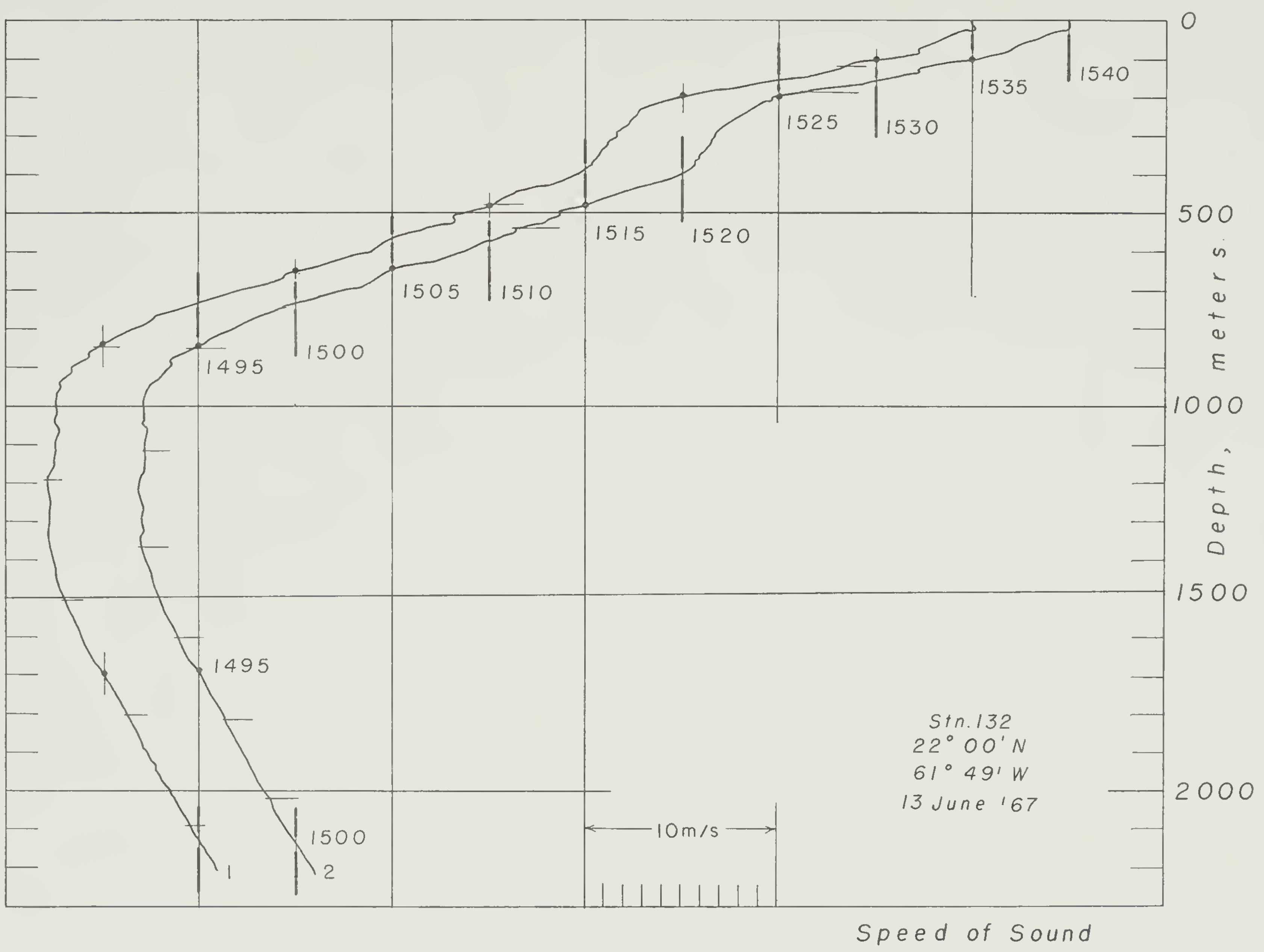


Fig. 16 Sound Speeds - Station 132

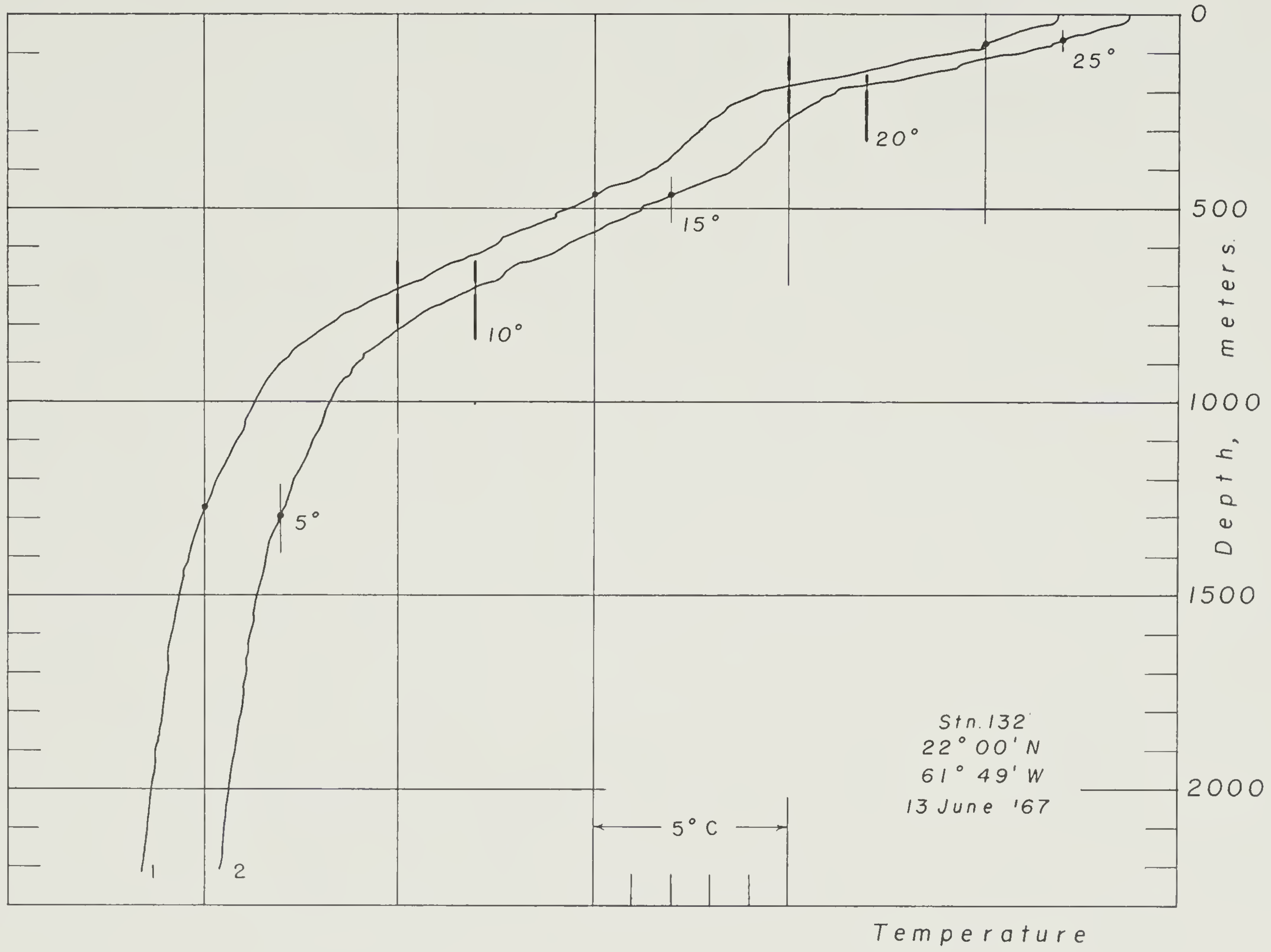


Fig. 17 Temperature - Station 132

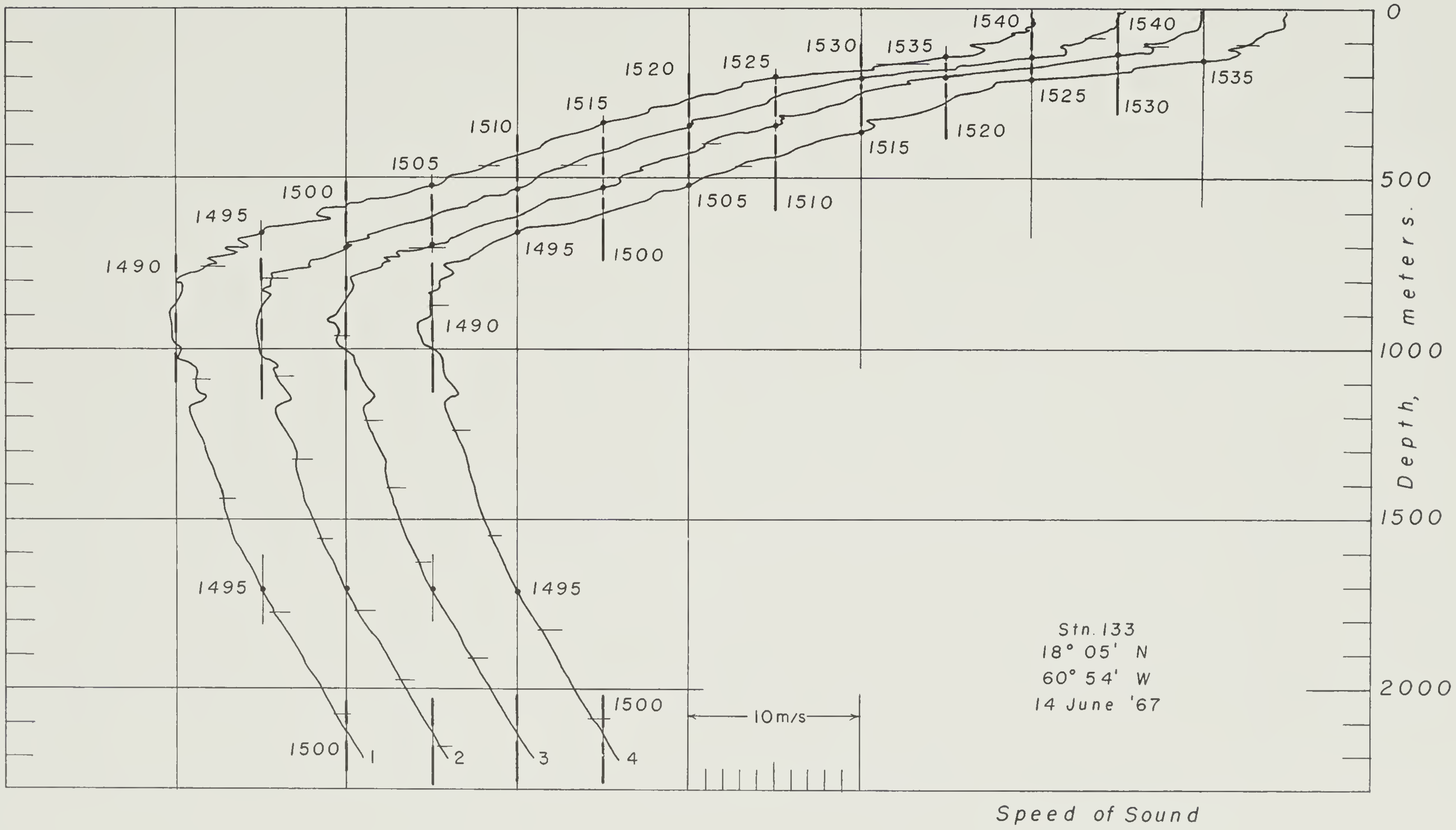


Fig. 18 Sound Speeds - Station 133

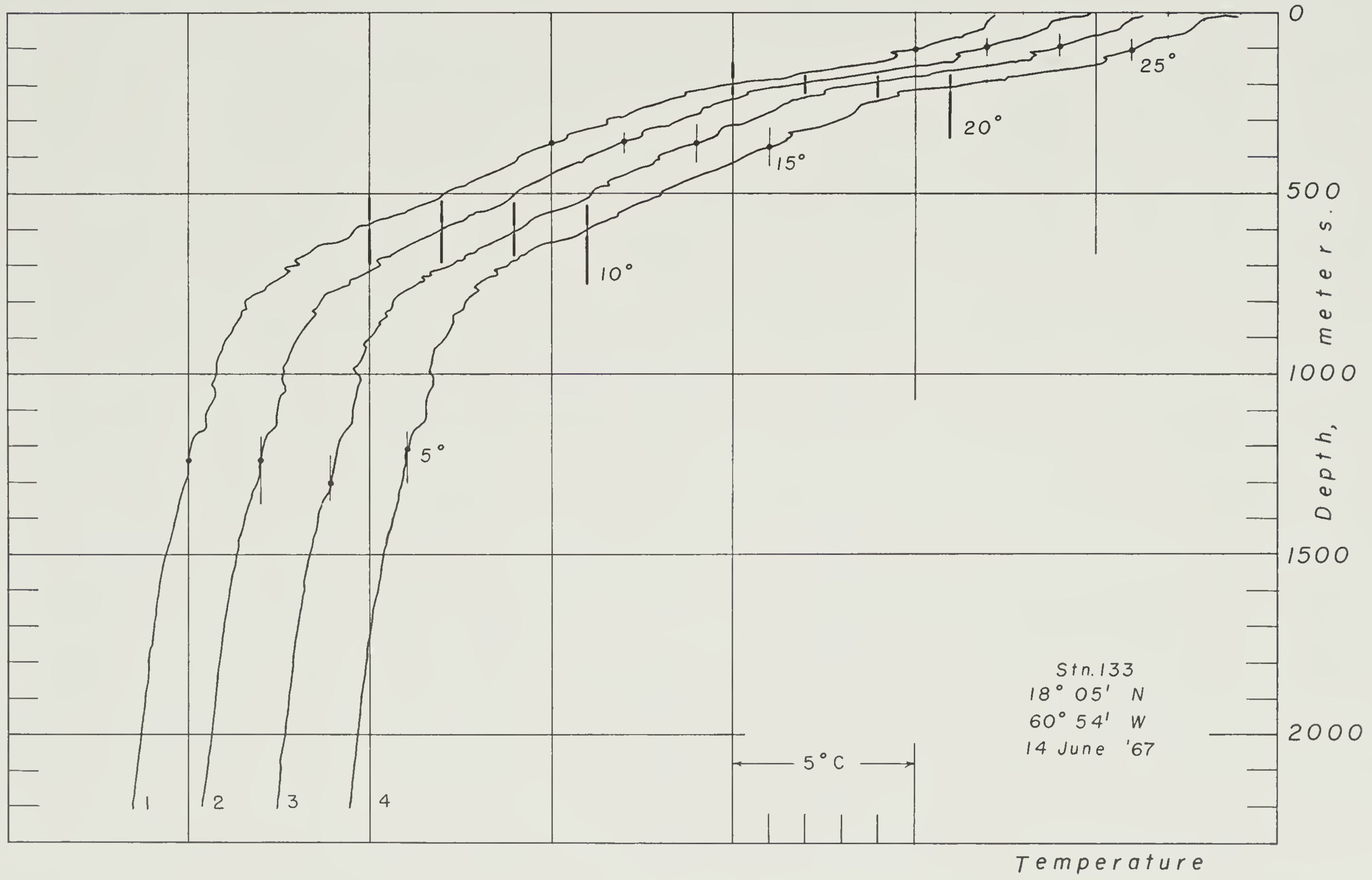


Fig. 19 Temperature - Station 133

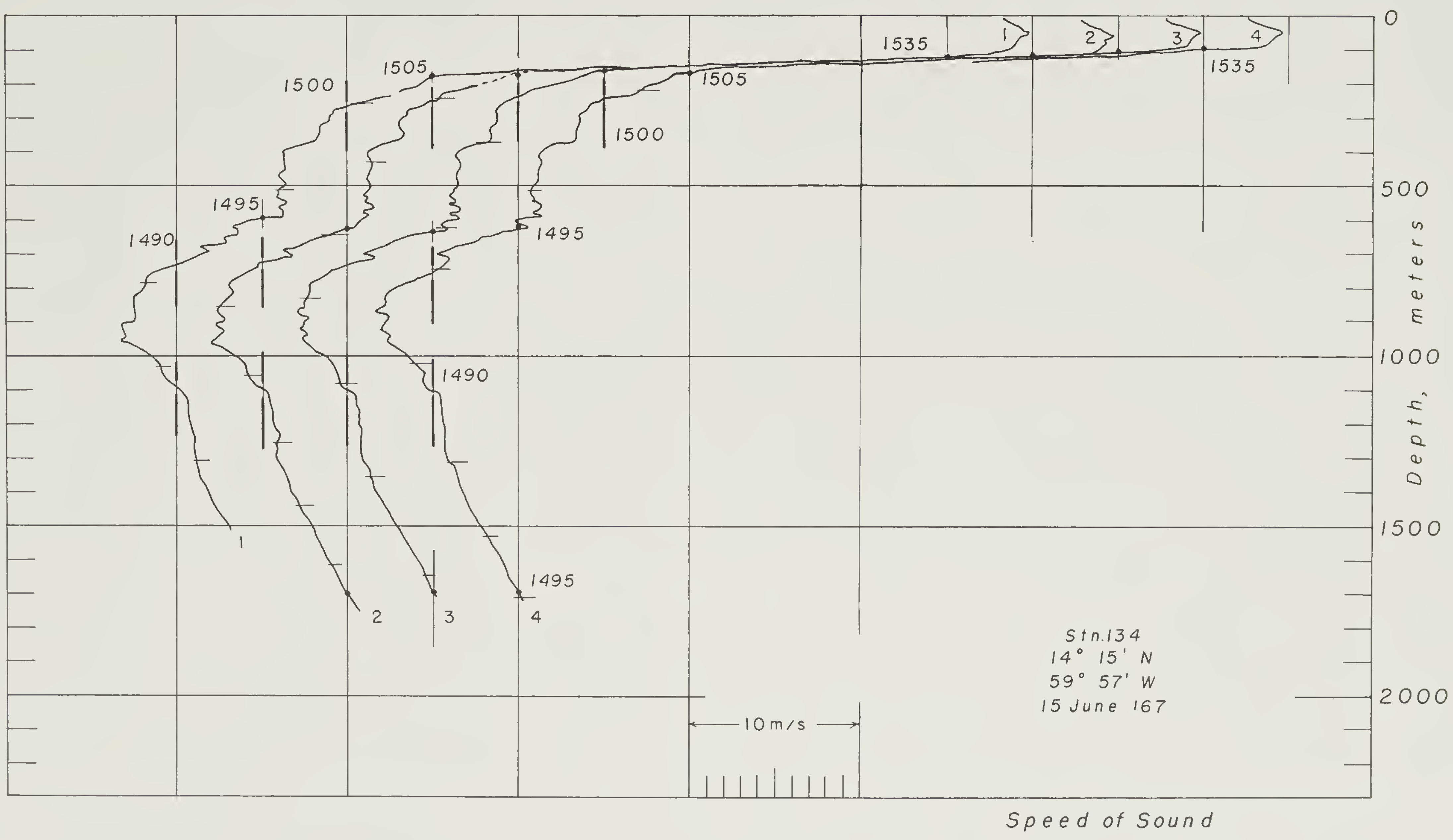


Fig. 20 Sound Speeds - Station 134

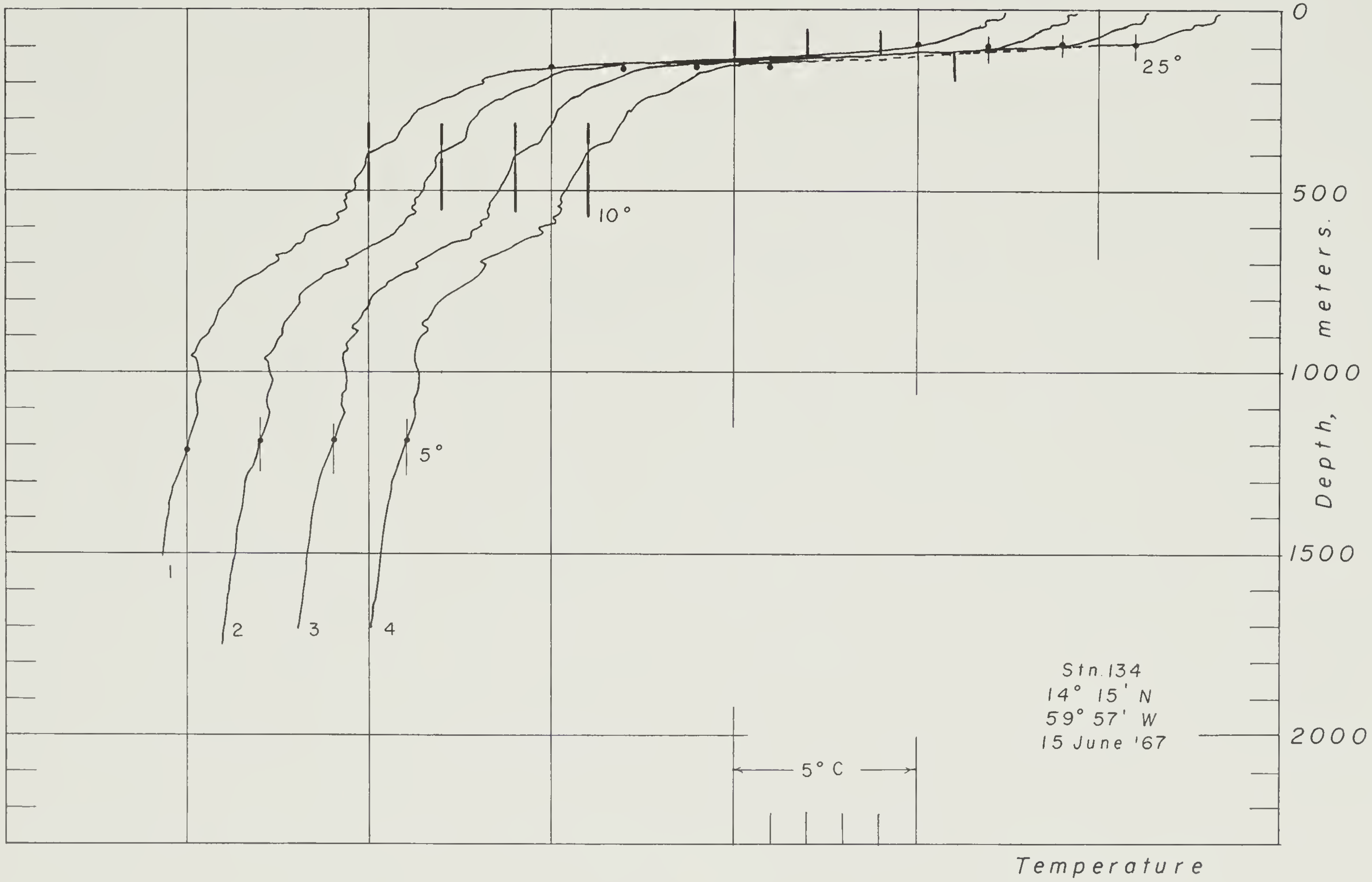


Fig. 21 Temperature - Station 134

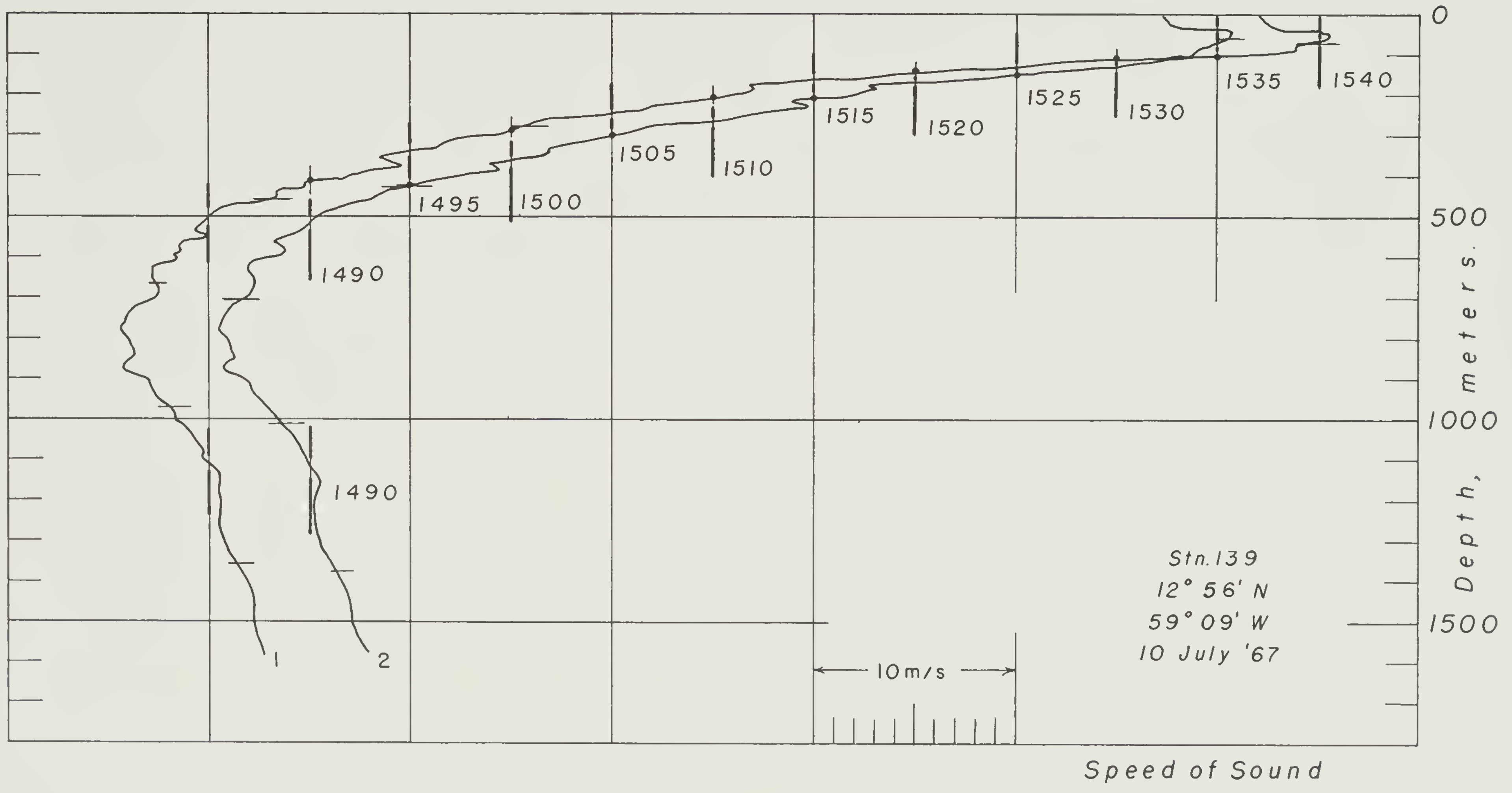


Fig. 22 Sound Speeds - Station 139

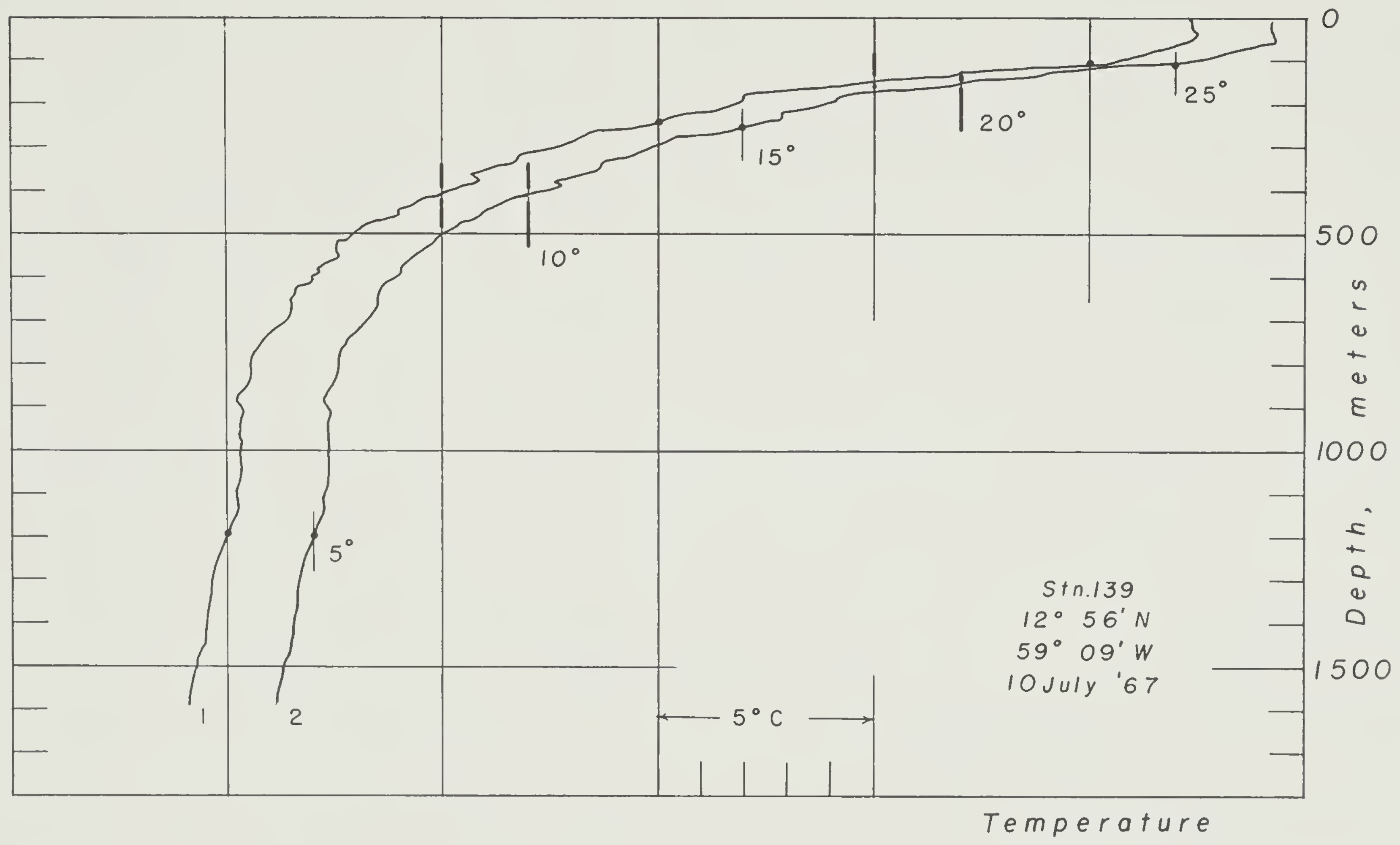


Fig. 23 Temperature - Station 139

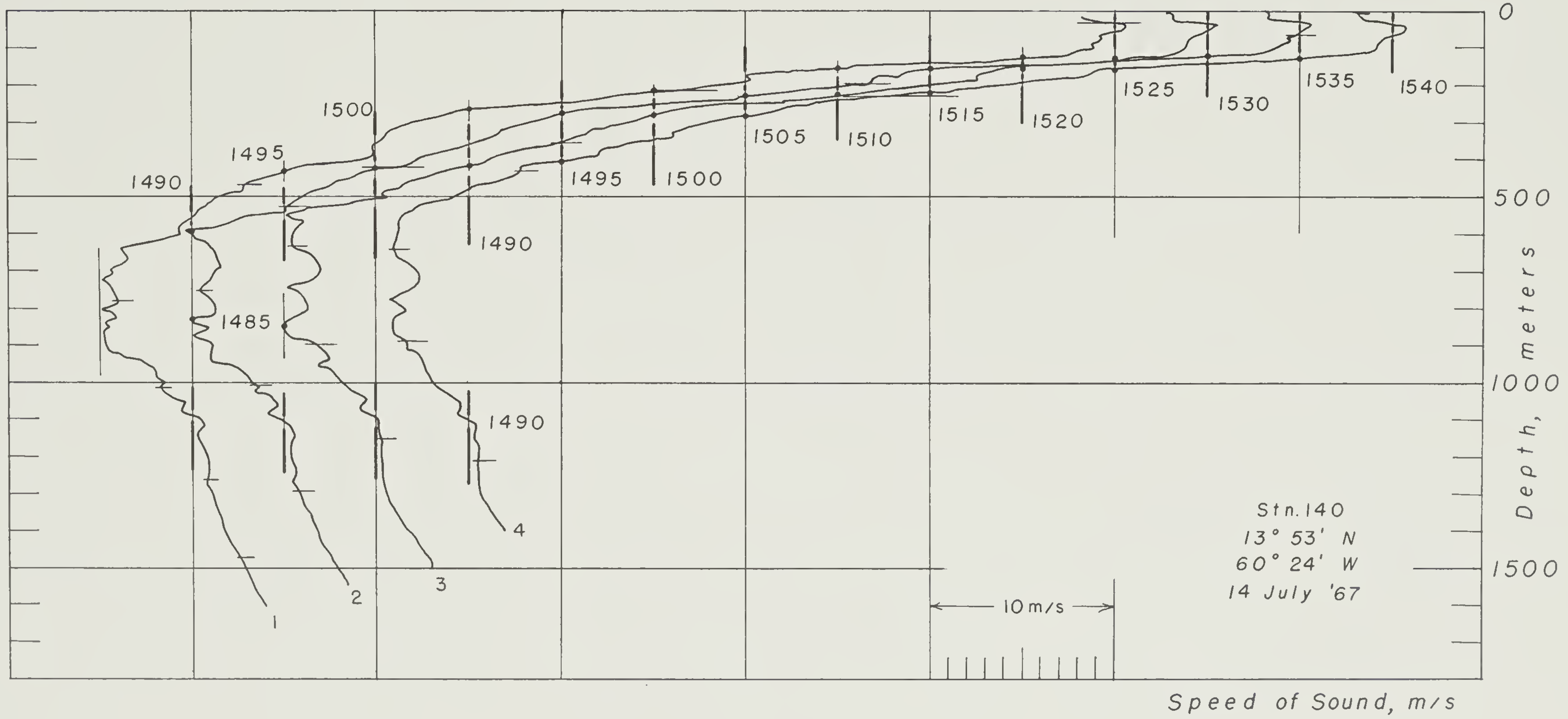


Fig. 24 Sound Speeds - Station 140

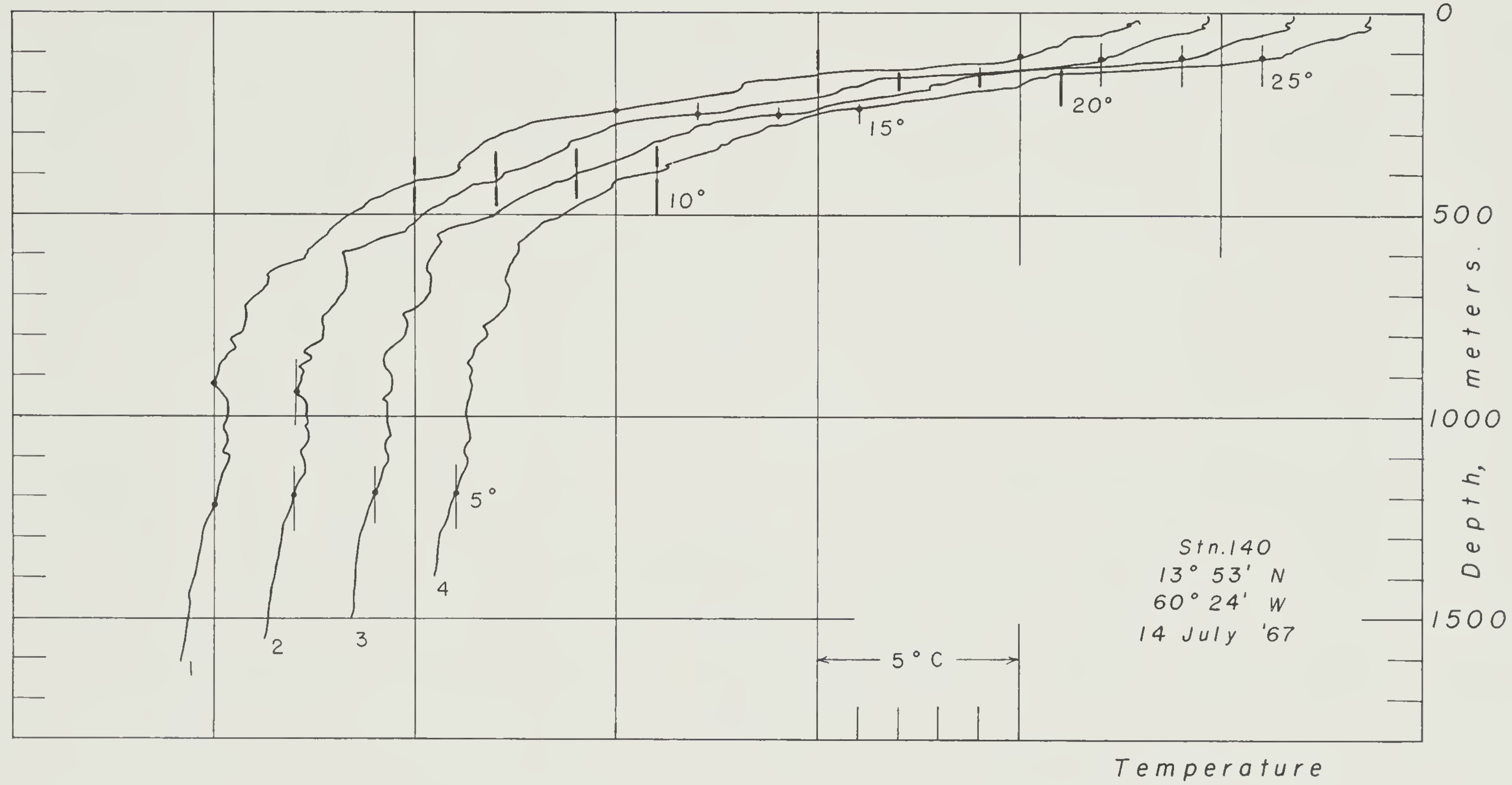


Fig. 25 *Temperature* - Station 140

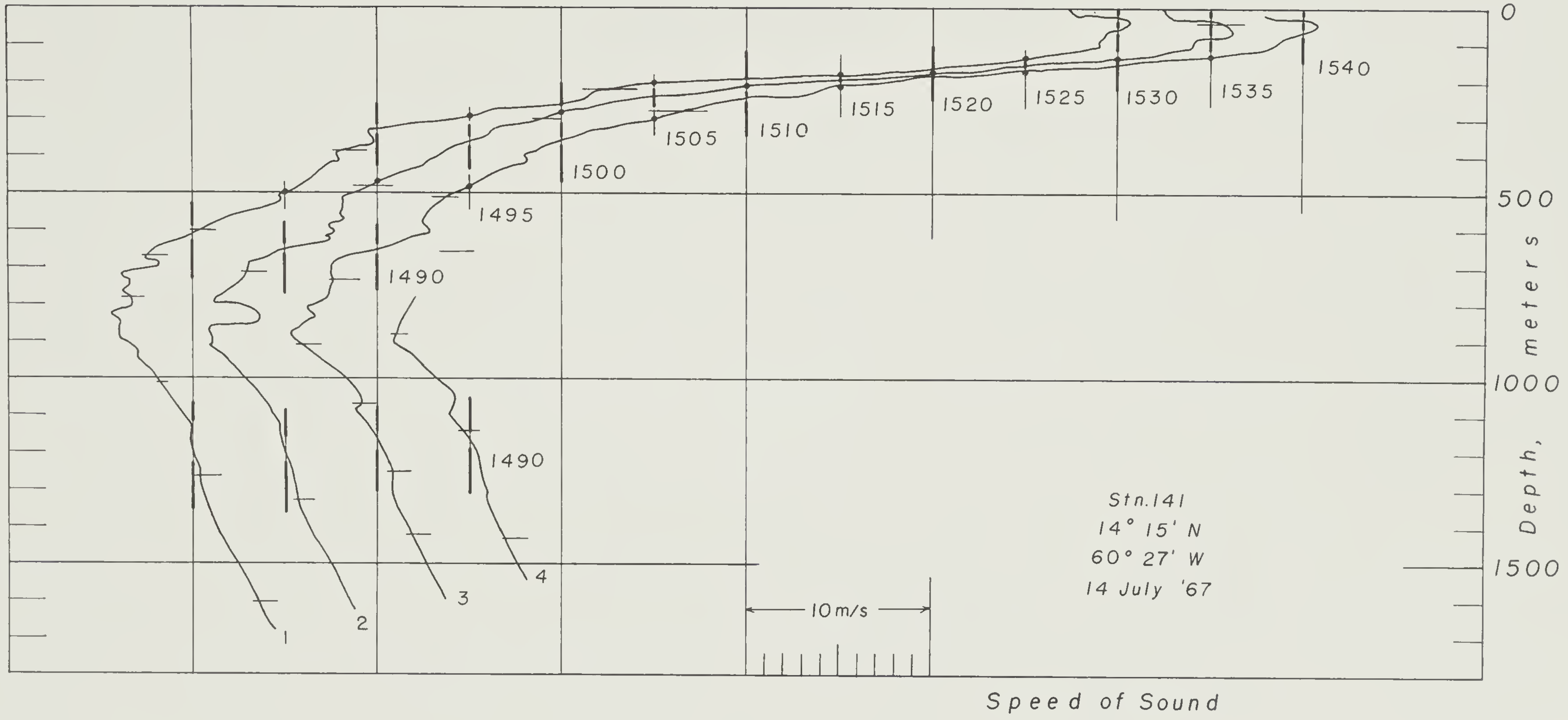


Fig. 26 Sound Speeds - Station 141

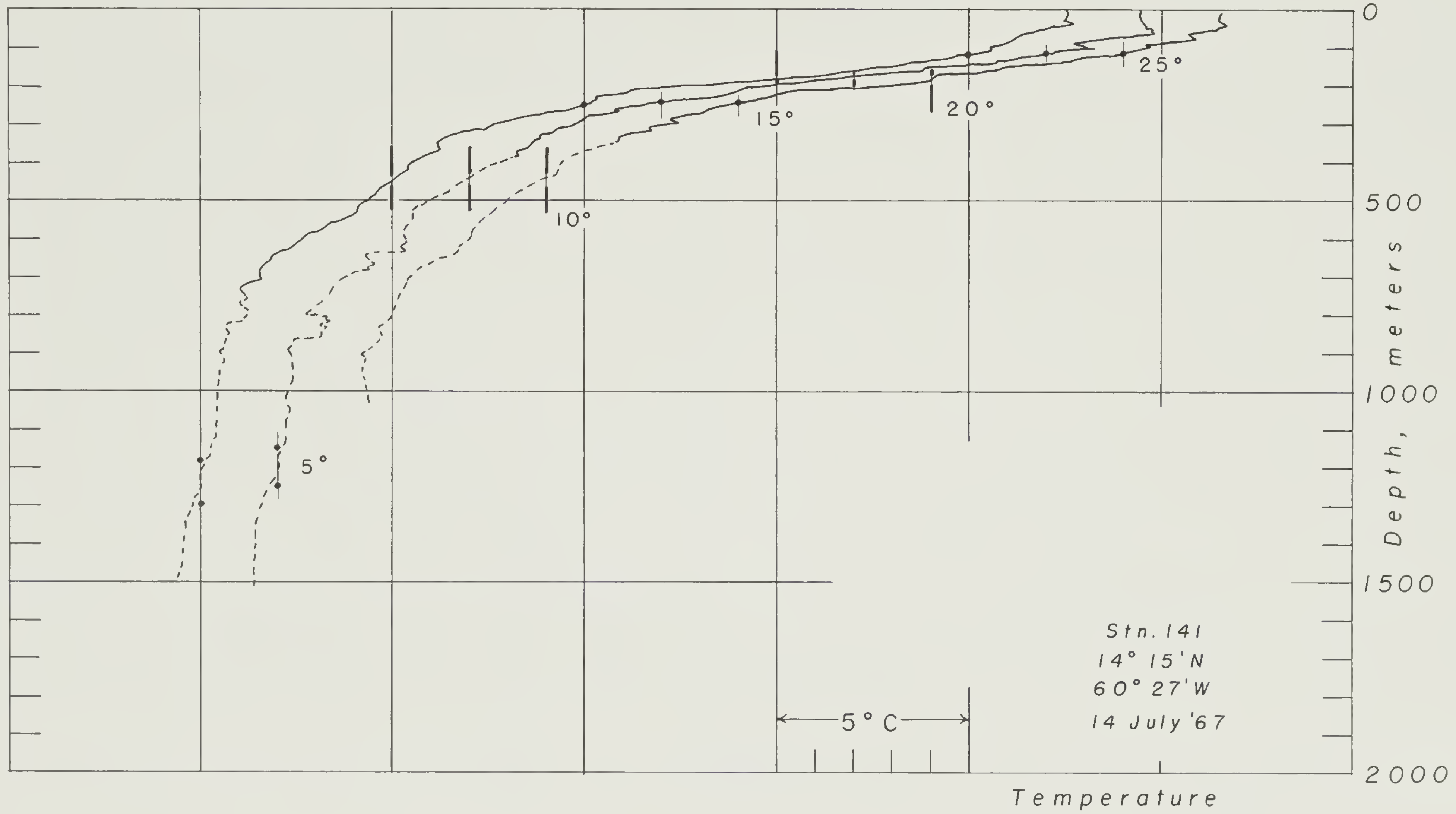


Fig. 27 Temperature - Station 141

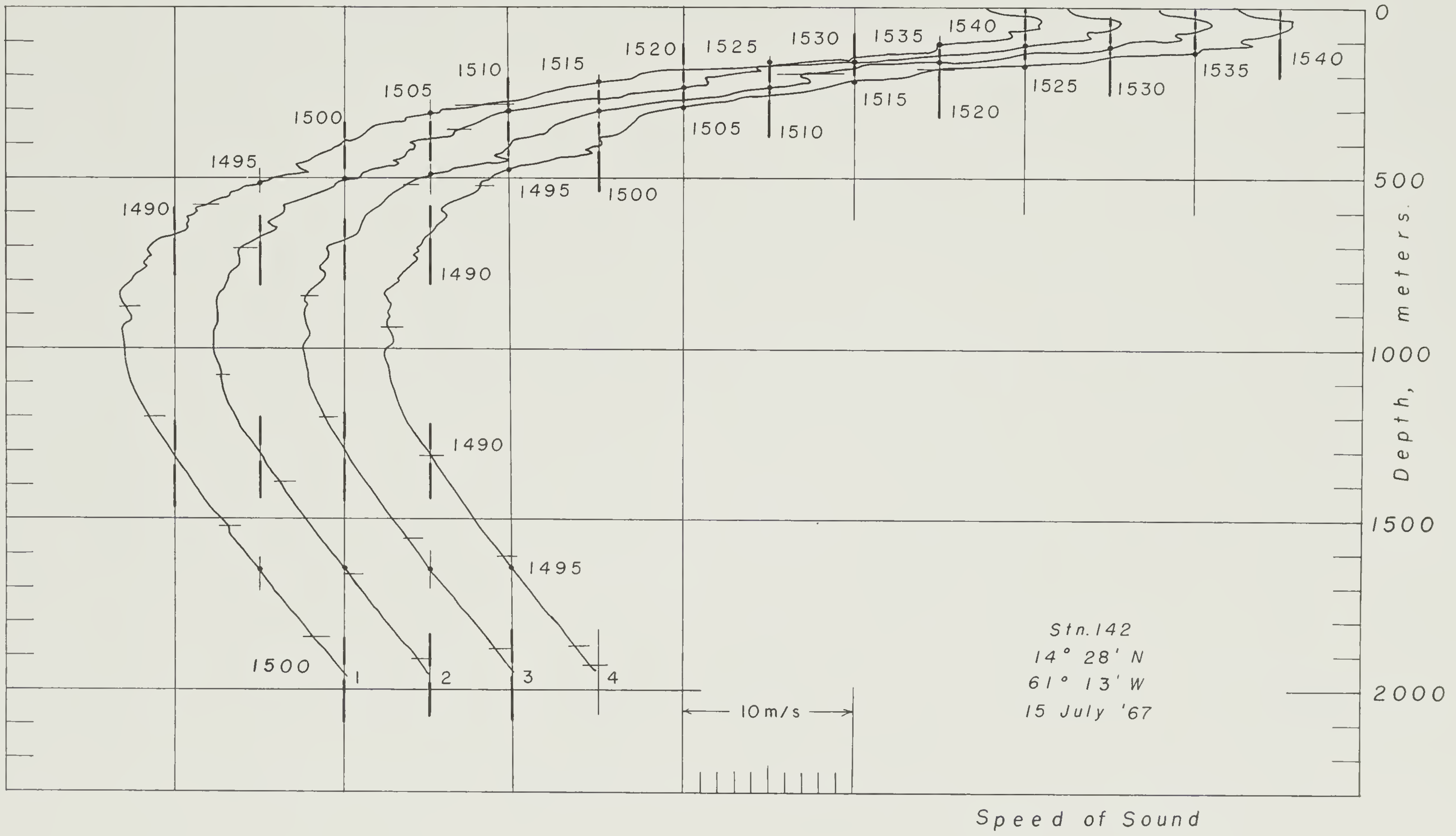


Fig. 28 Sound Speeds - Station 142

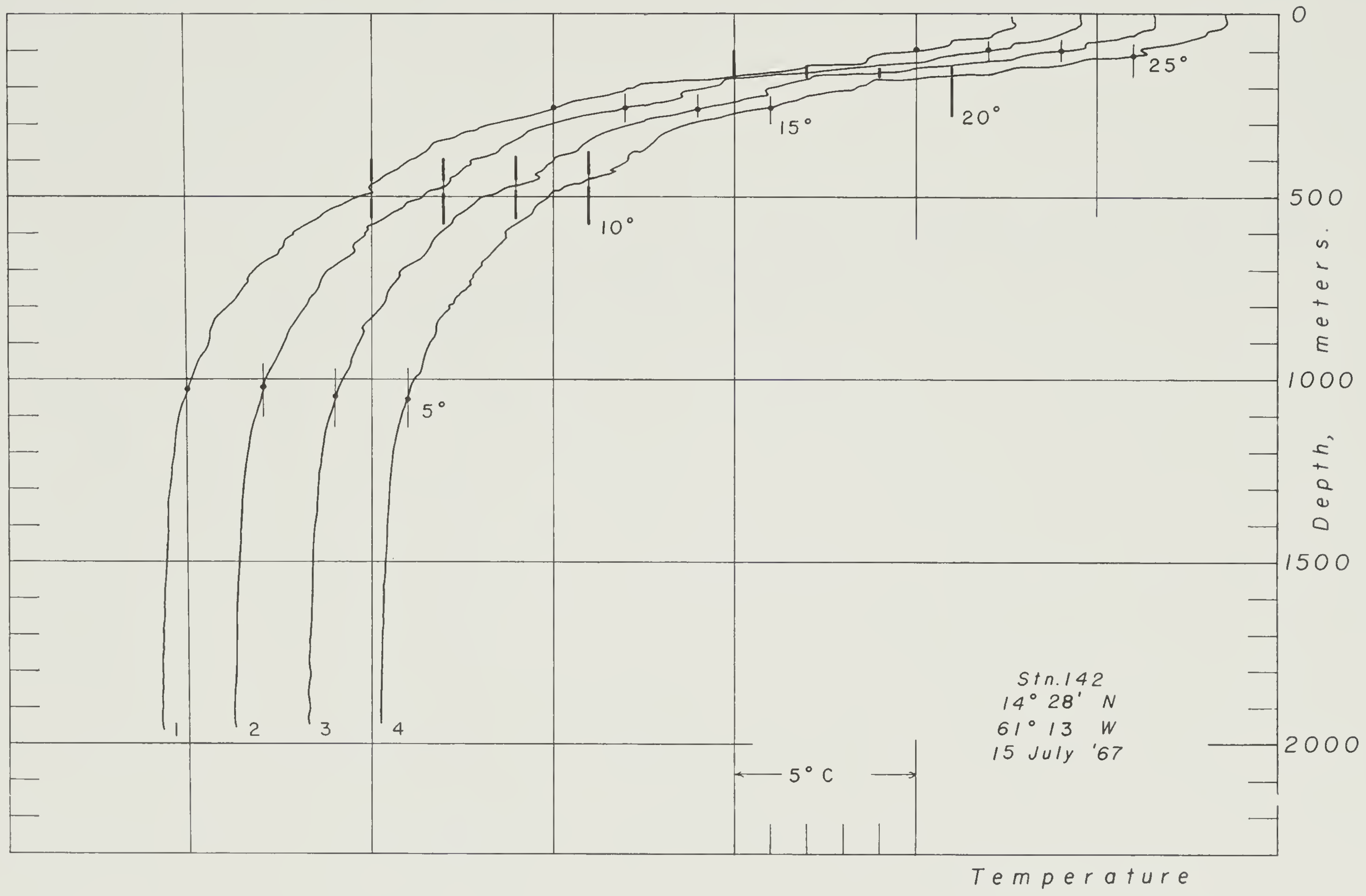


Fig. 29 *Temperature* - Station 142

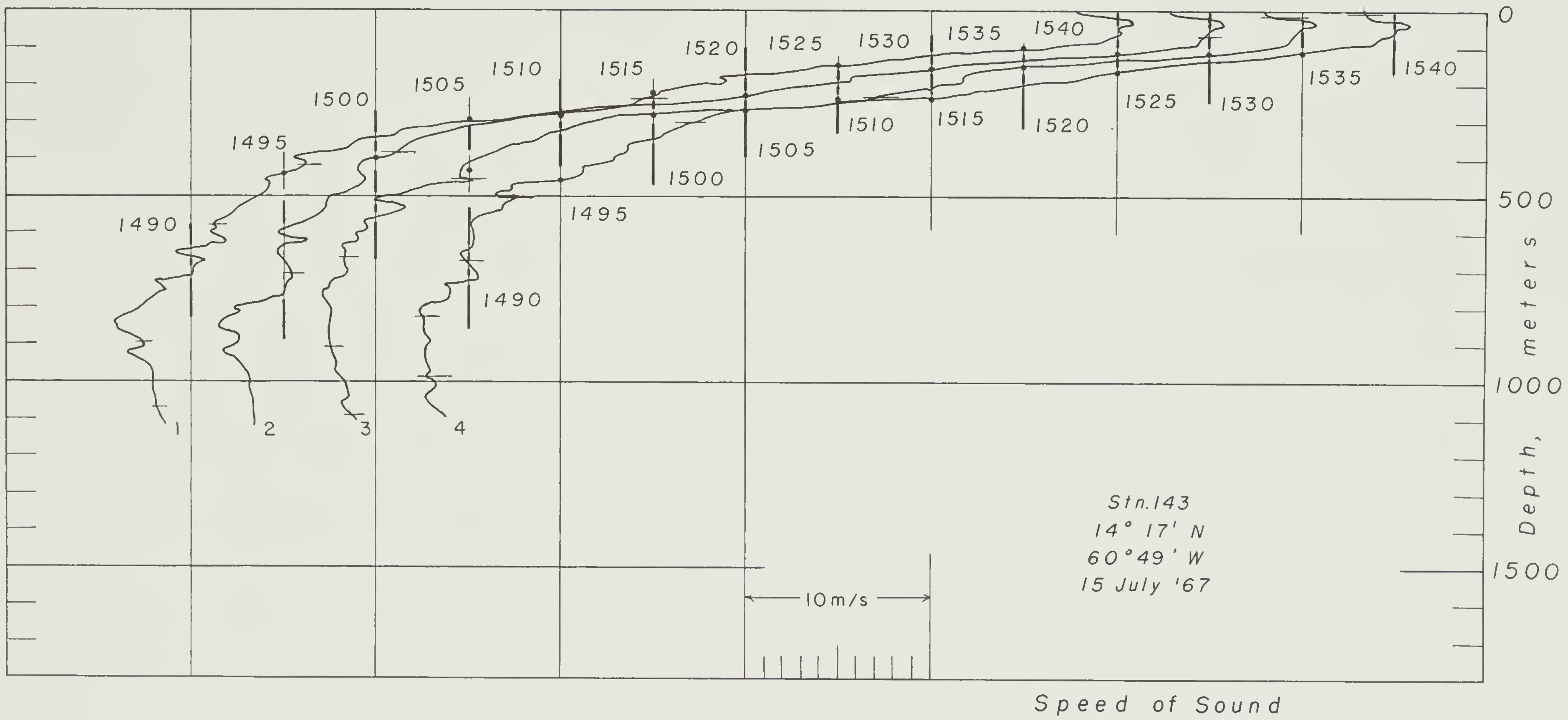


Fig. 30 Sound Speeds - Station 143

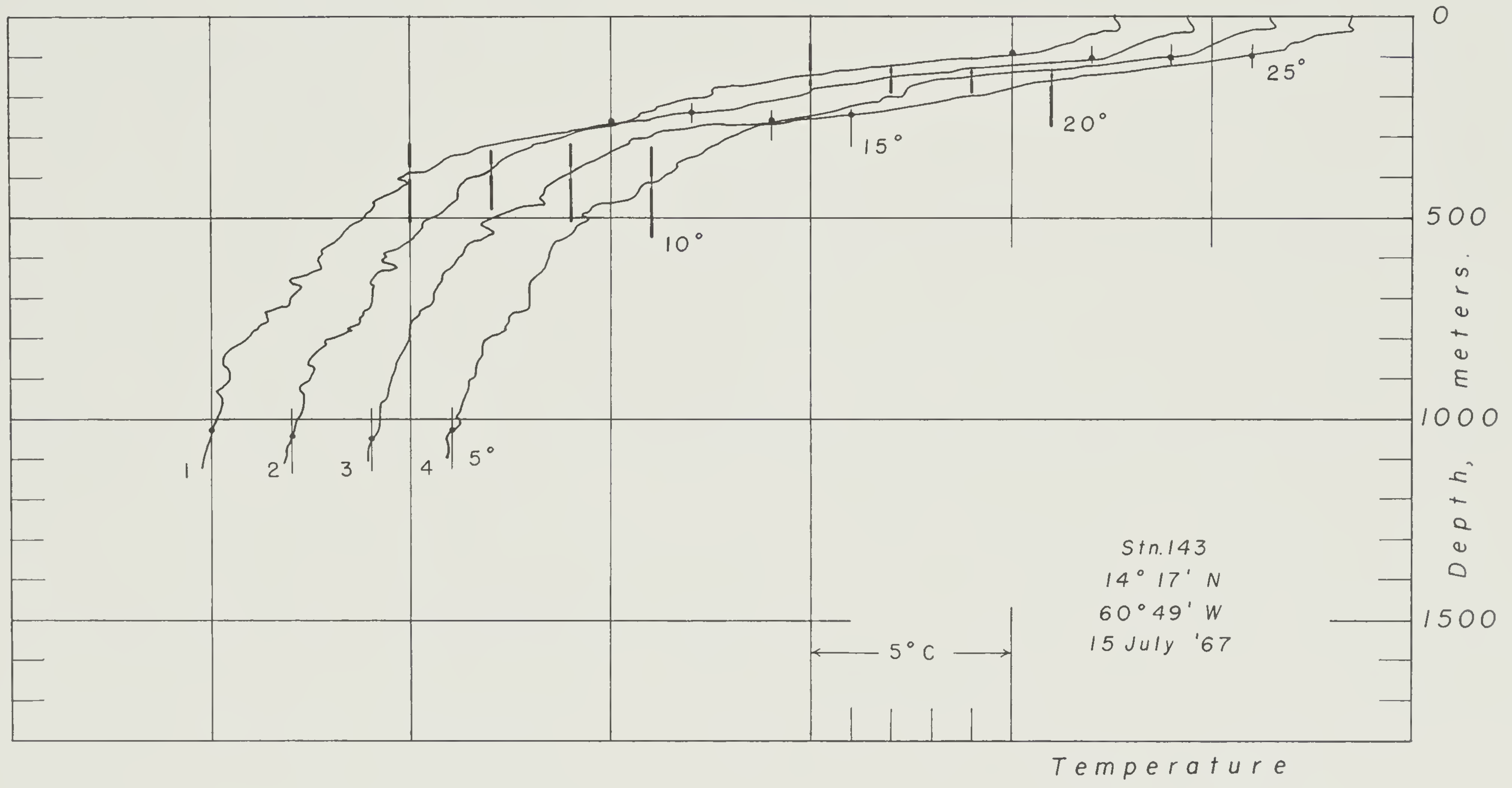


Fig. 31 Temperature - Station 143

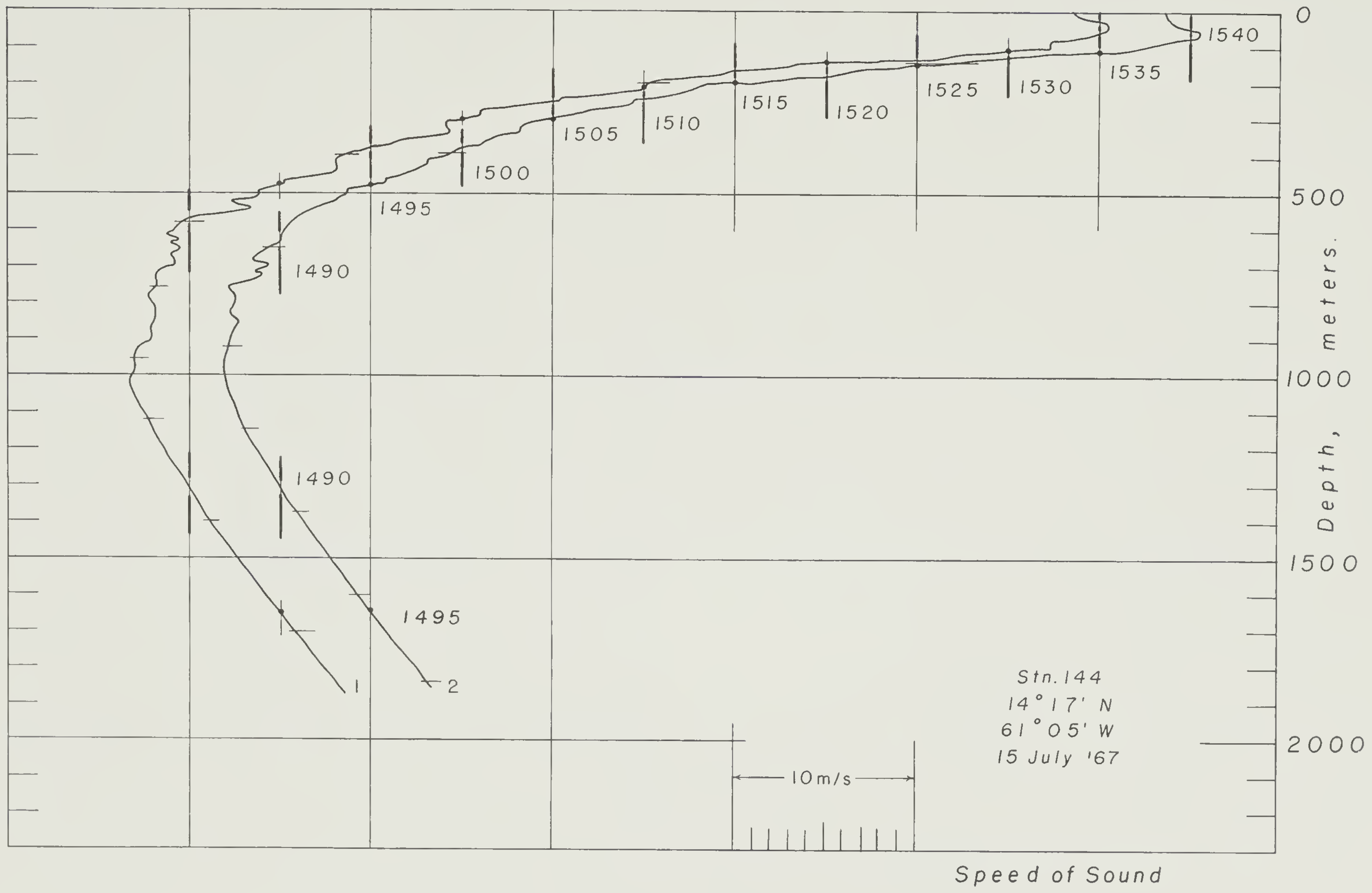


Fig. 32 Sound Speeds - Station 144

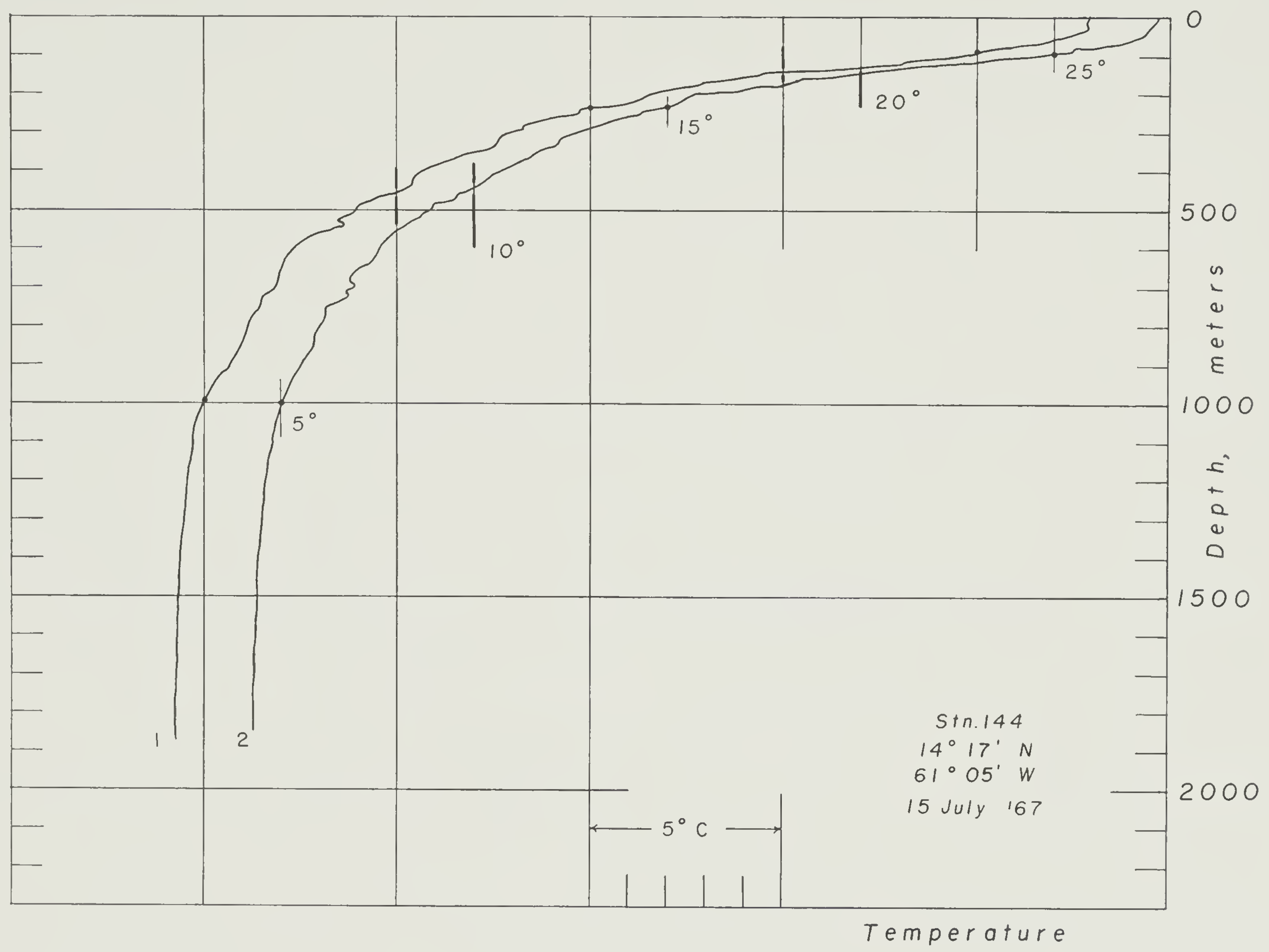


Fig. 33 Temperature - Station 144

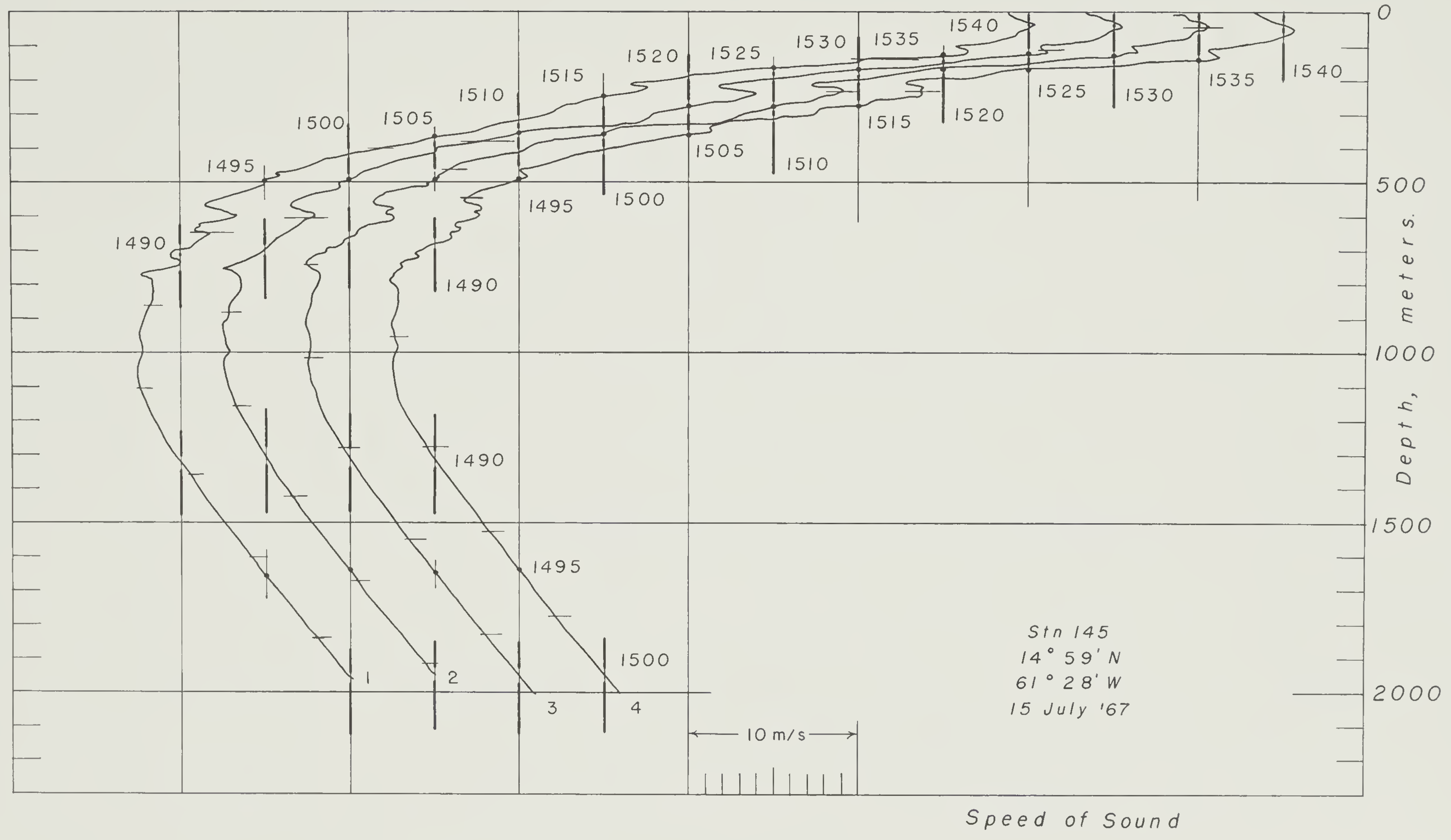


Fig. 34 Sound Speeds - Station 145

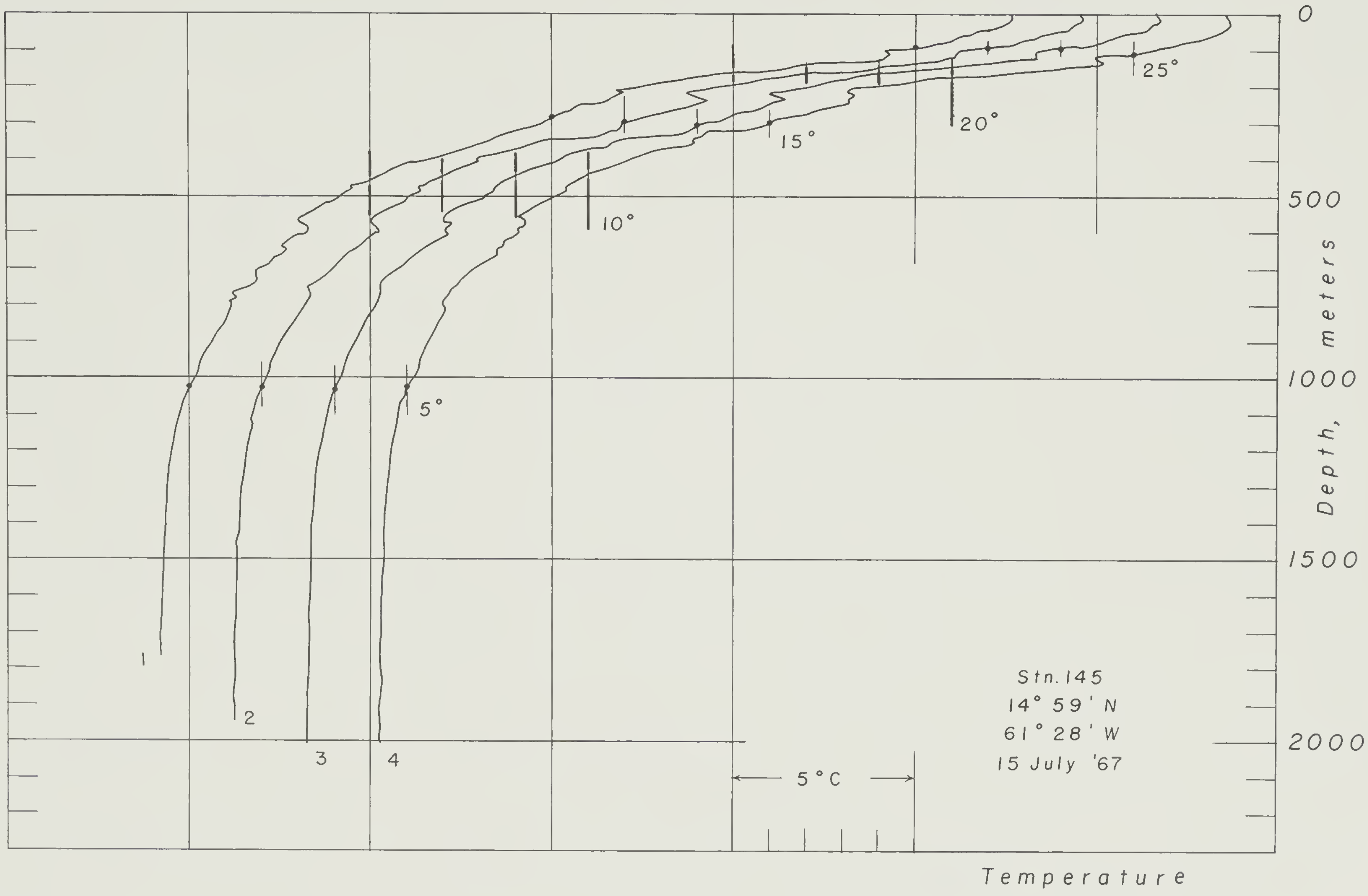


Fig. 35 Temperature - Station 145

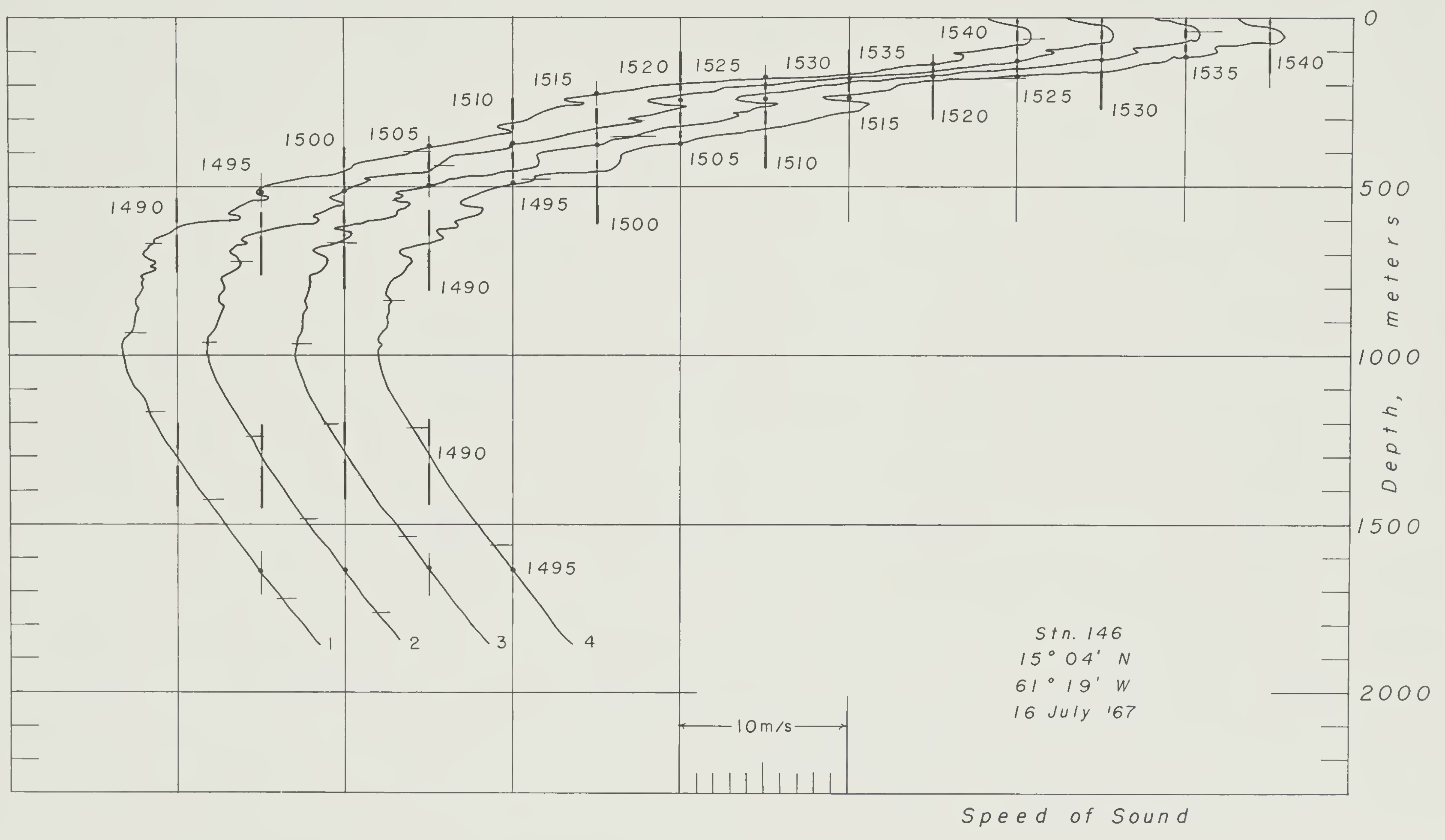


Fig. 36 Sound Speeds - Station 146

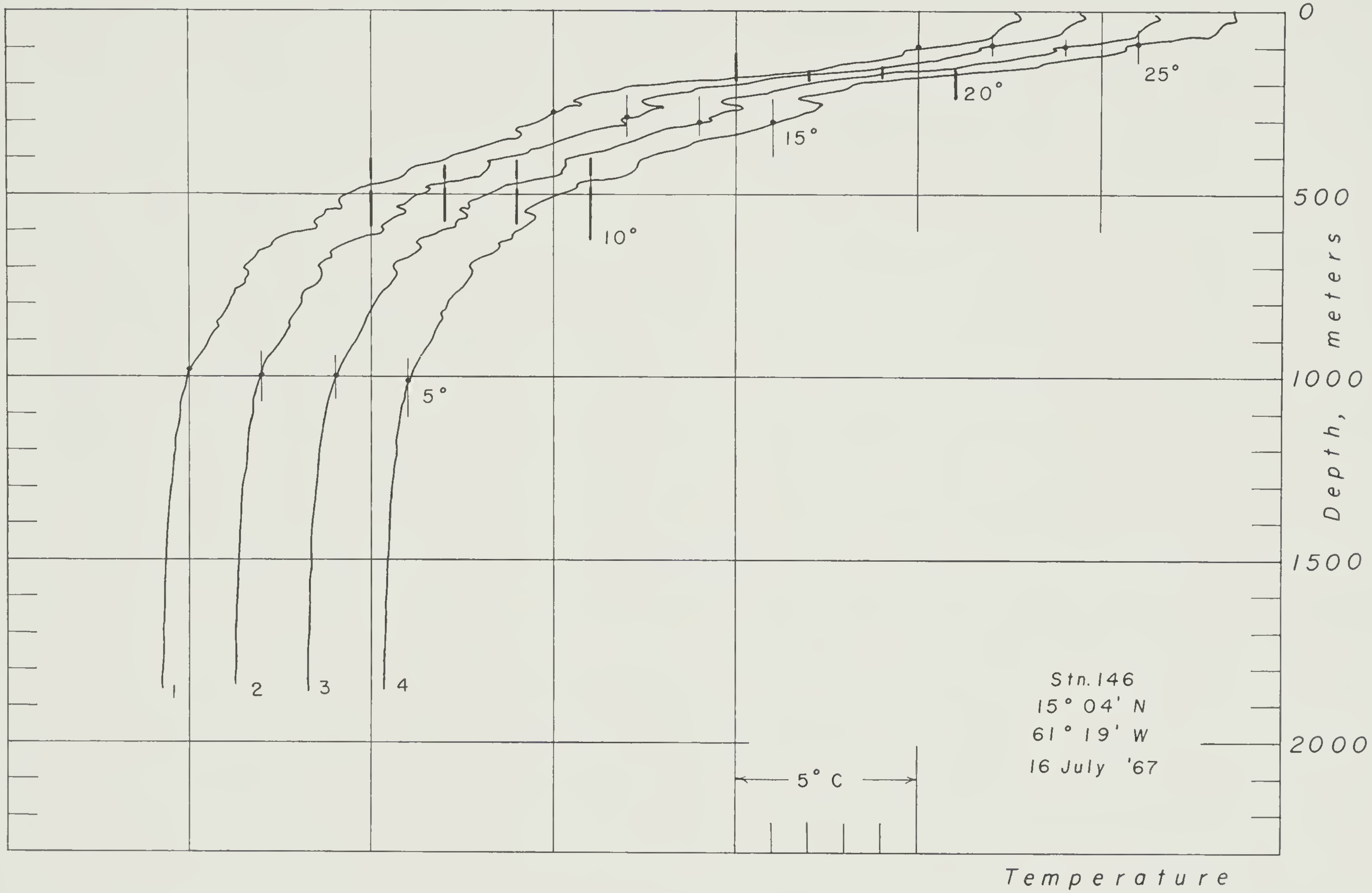


Fig. 37 Temperature - Station 146

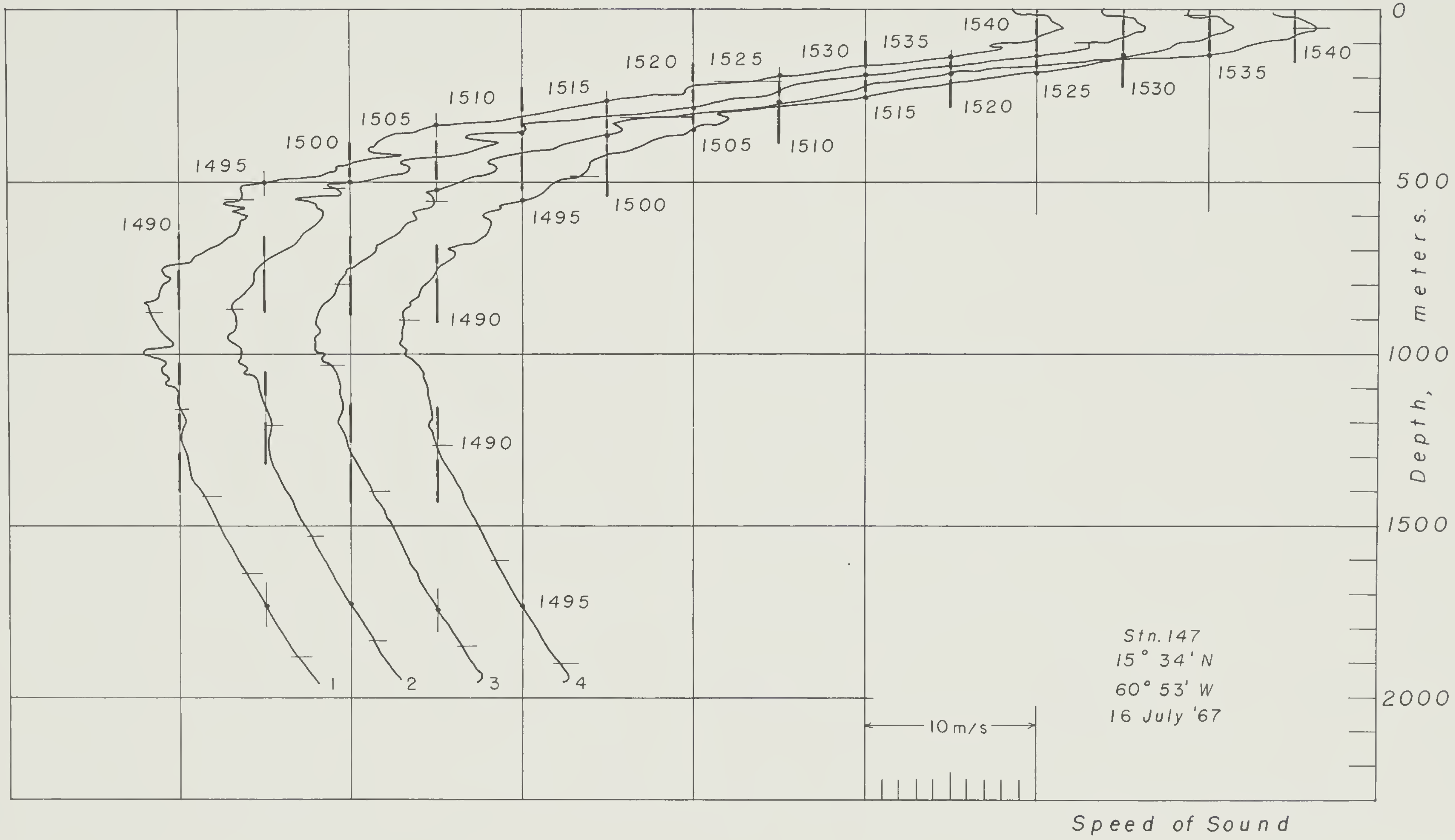


Fig. 38 Sound Speeds - Station 147

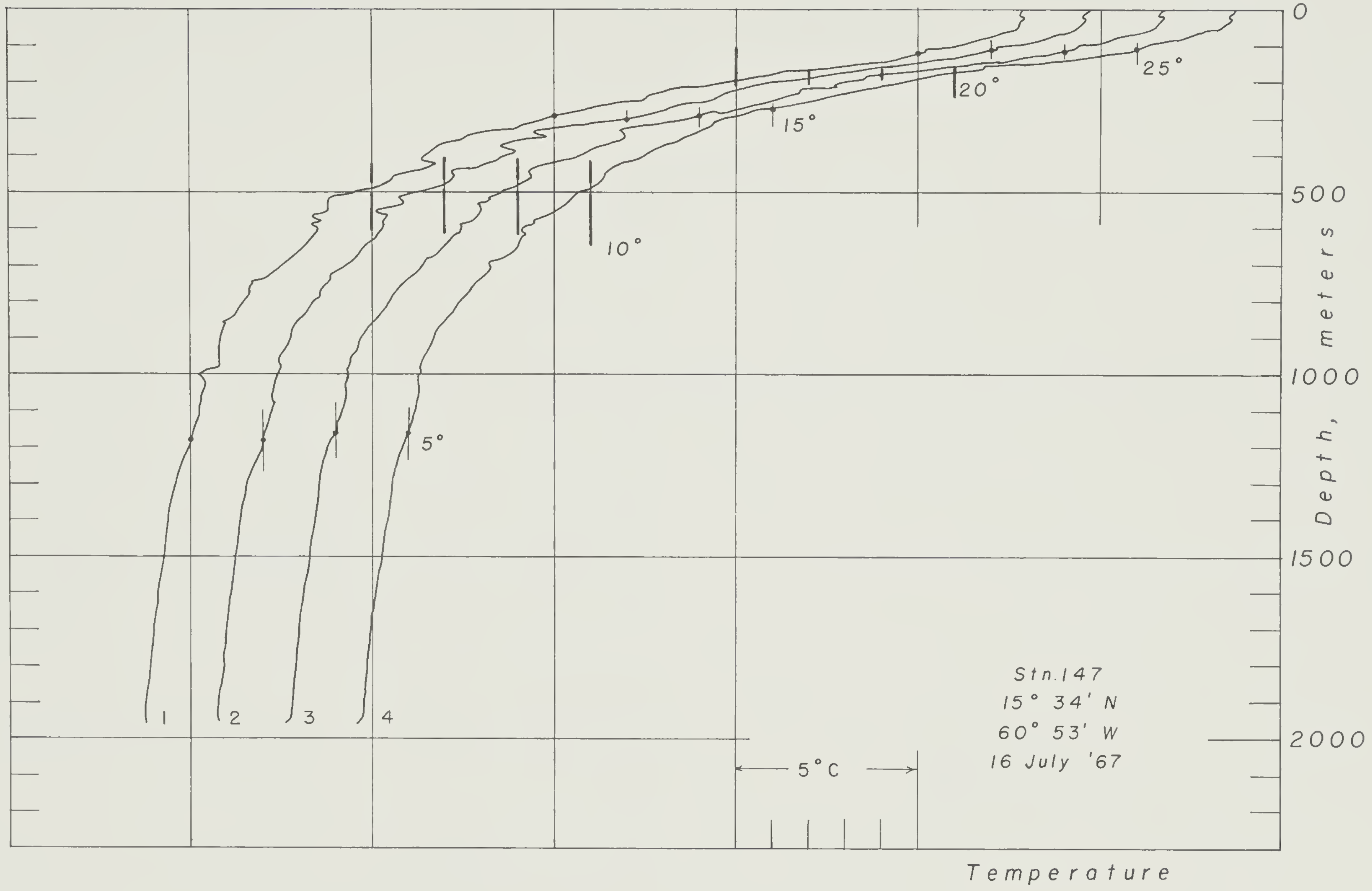


Fig. 39 Temperature - Station 147

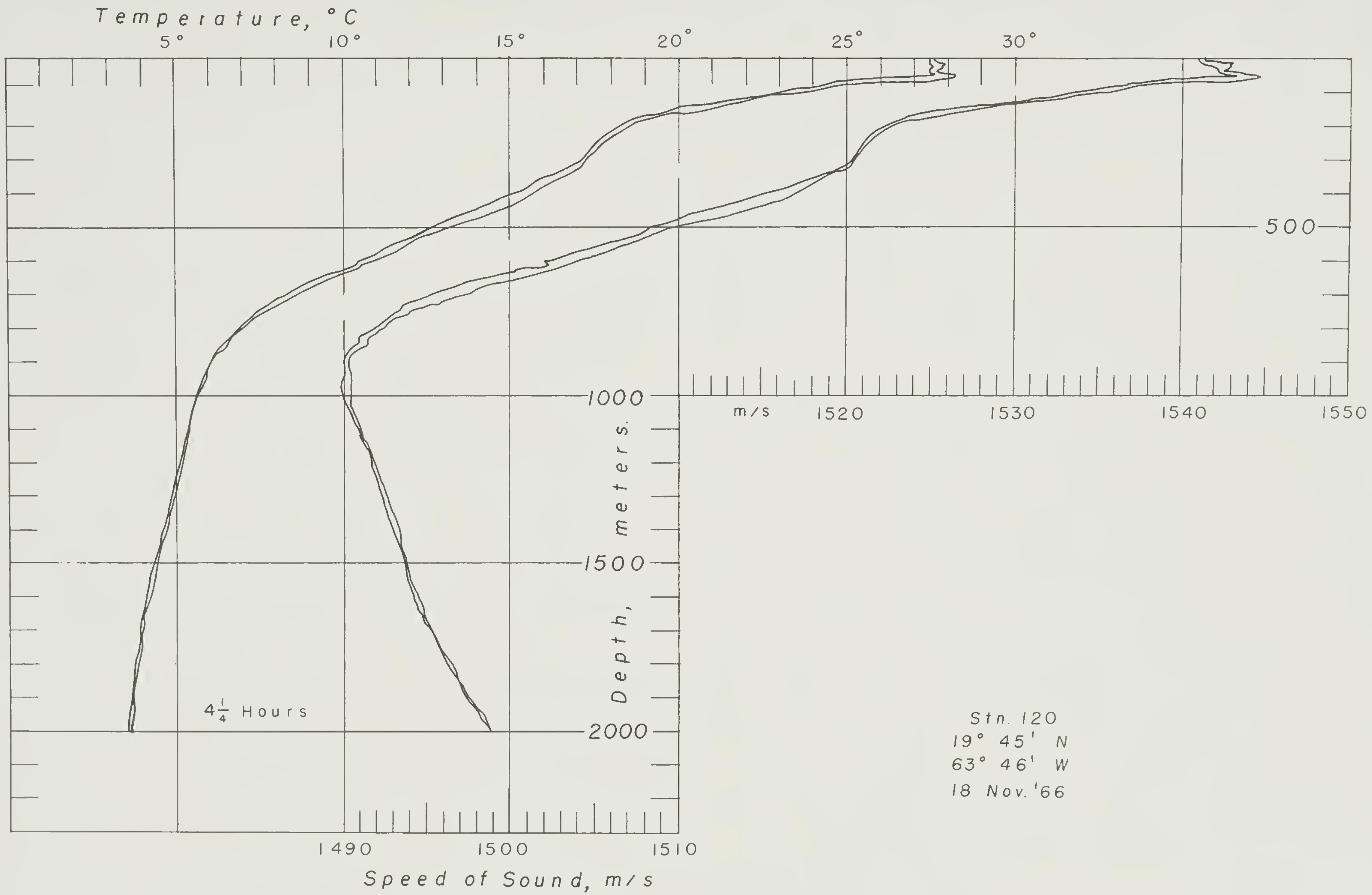


Fig. 40 *Envelope of Profiles - Station 120*

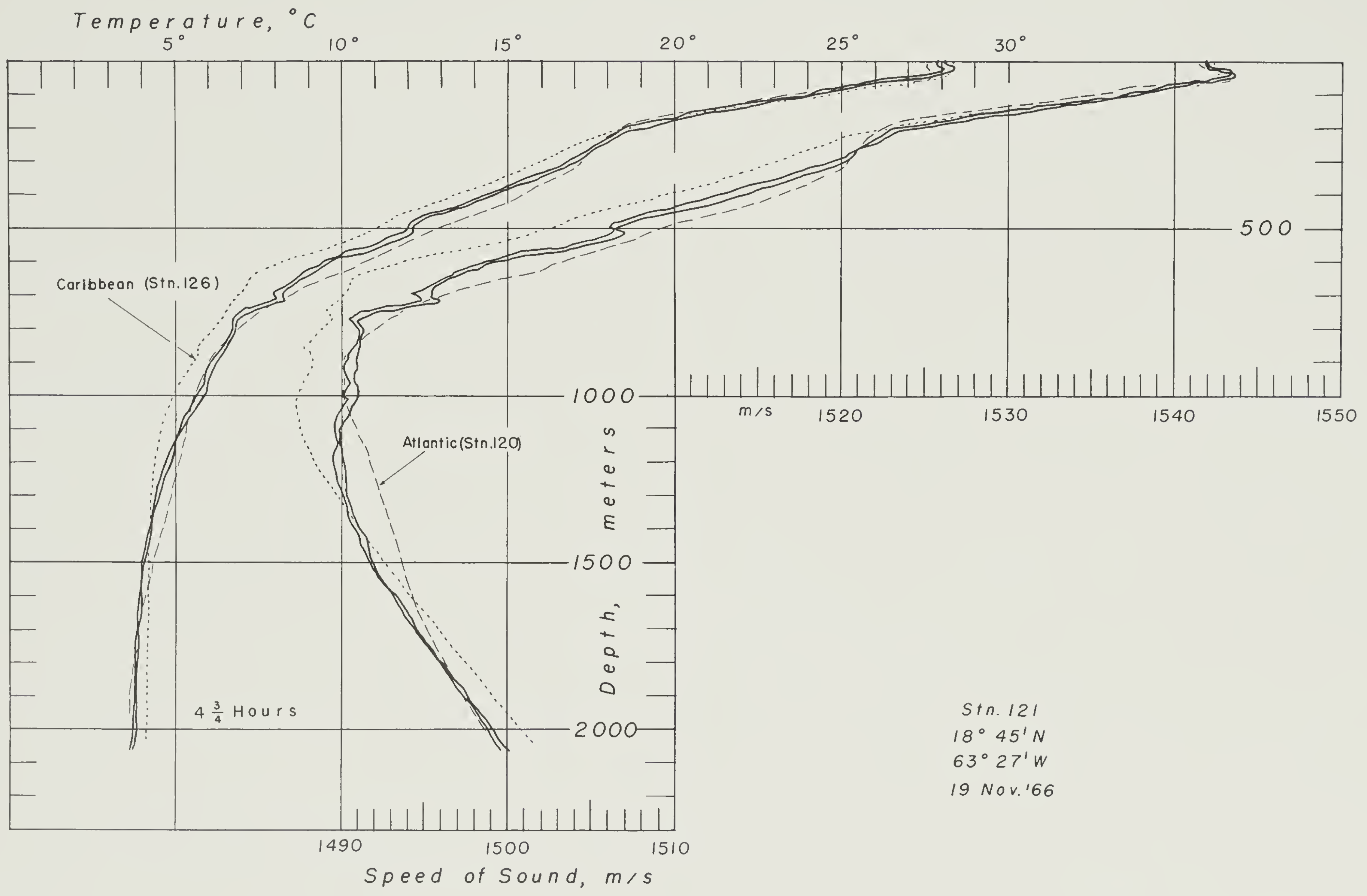


Fig. 41 *Envelope of Profiles* - Station 121

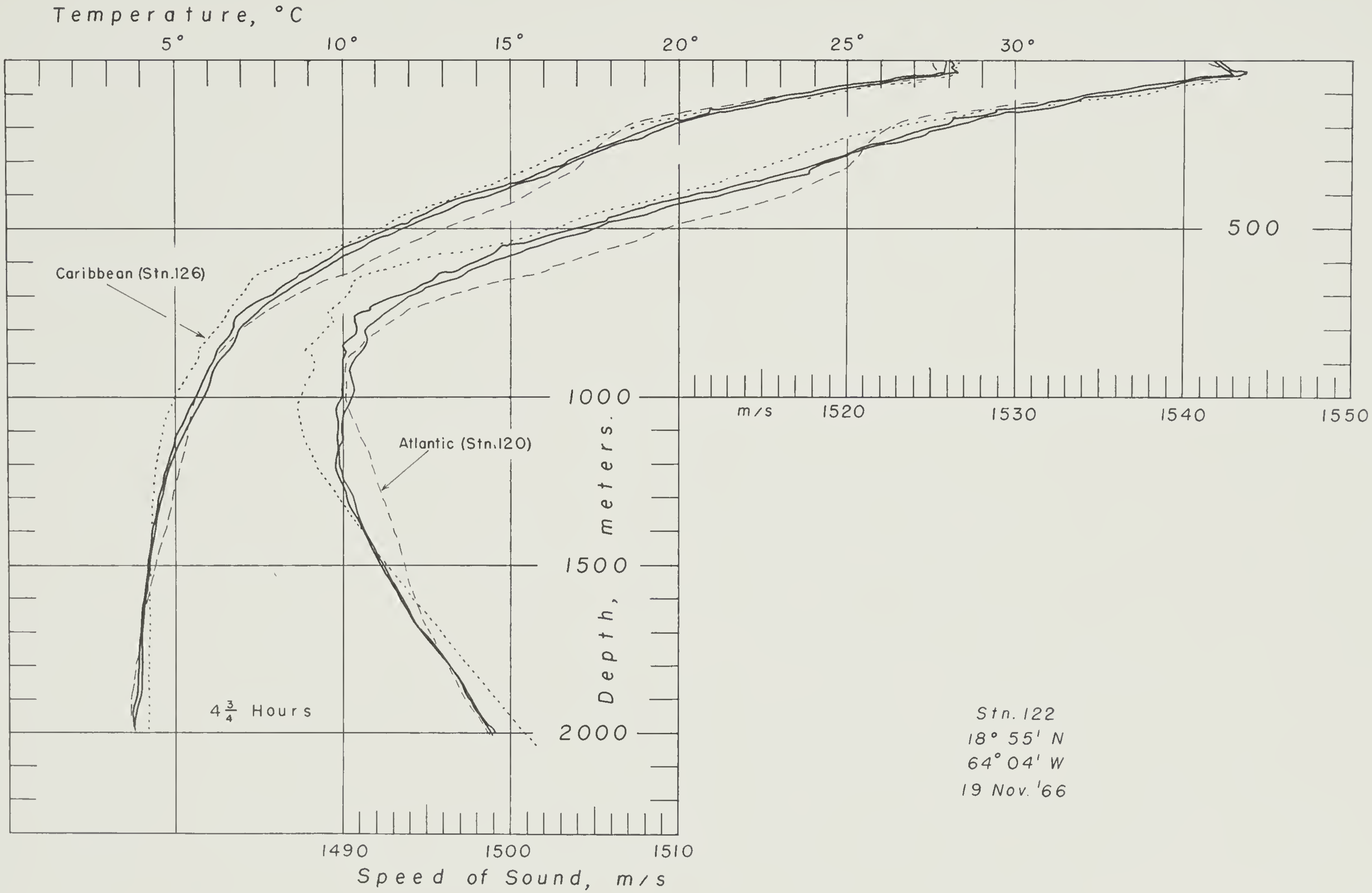


Fig. 42 *Envelope of Profiles* - Station 122

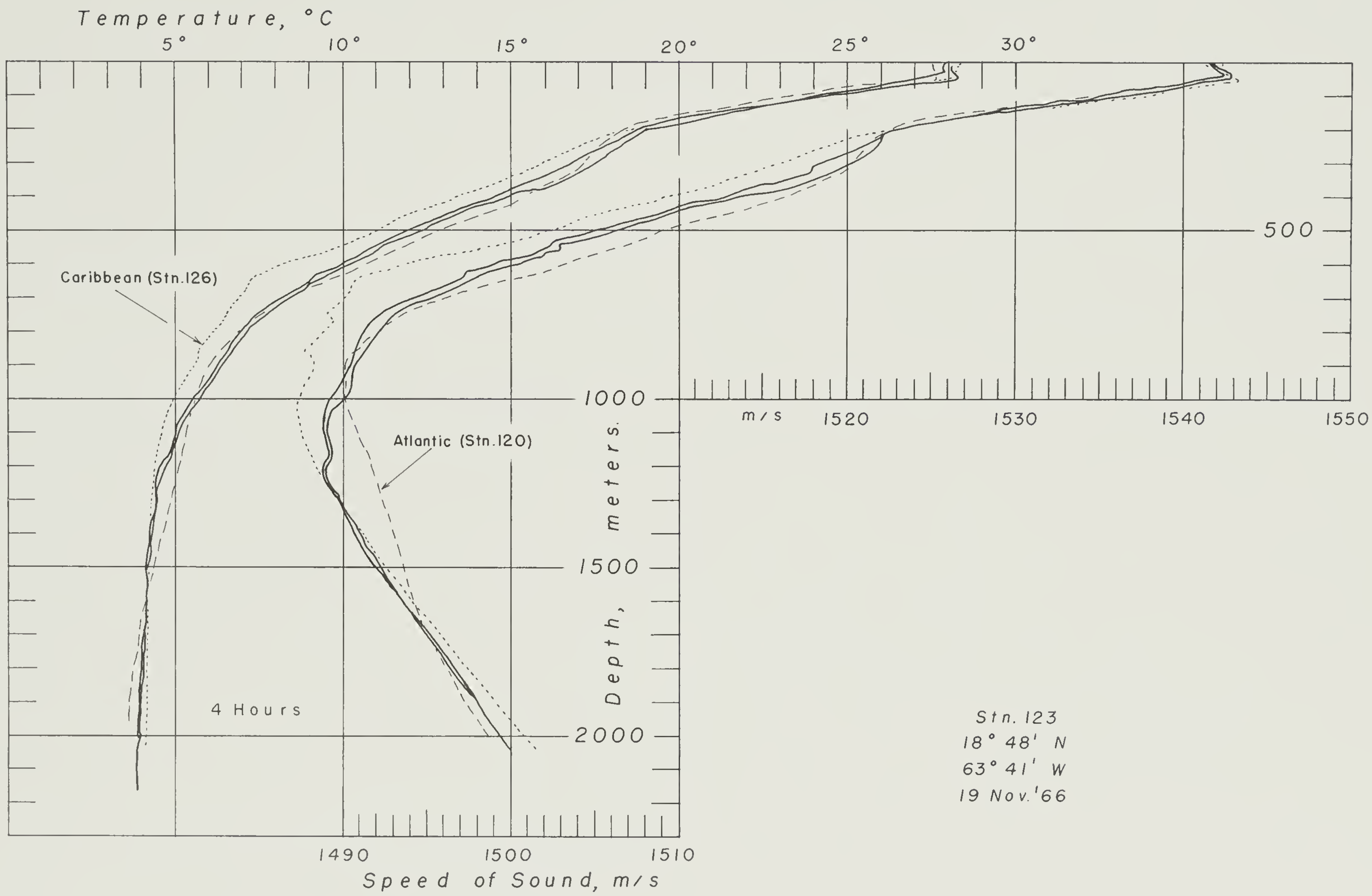


Fig. 43 *Envelope of Profiles* - Station 123

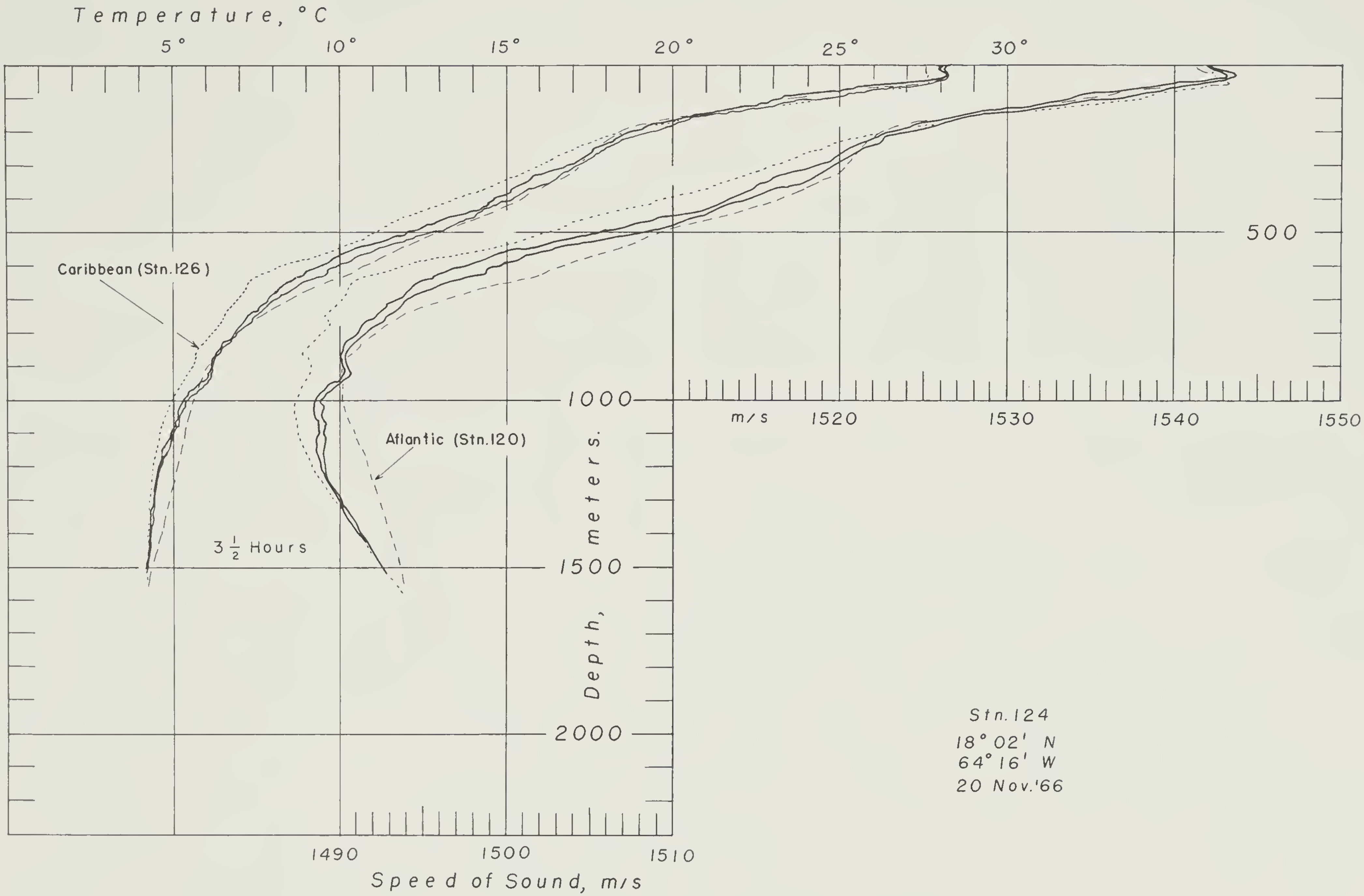


Fig. 44 *Envelope of Profiles* - Station 124

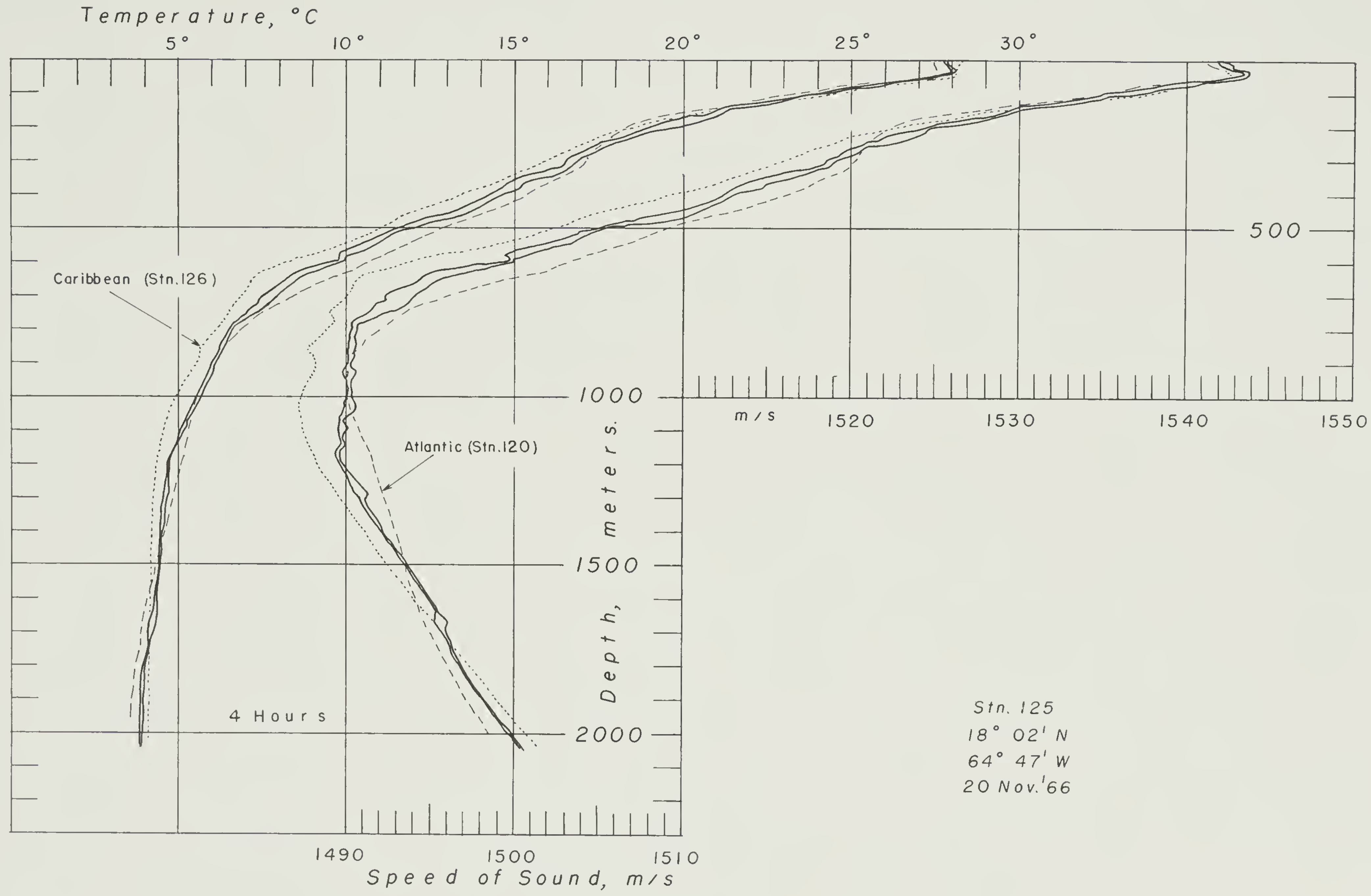


Fig. 45 Envelope of Profiles - Station 125

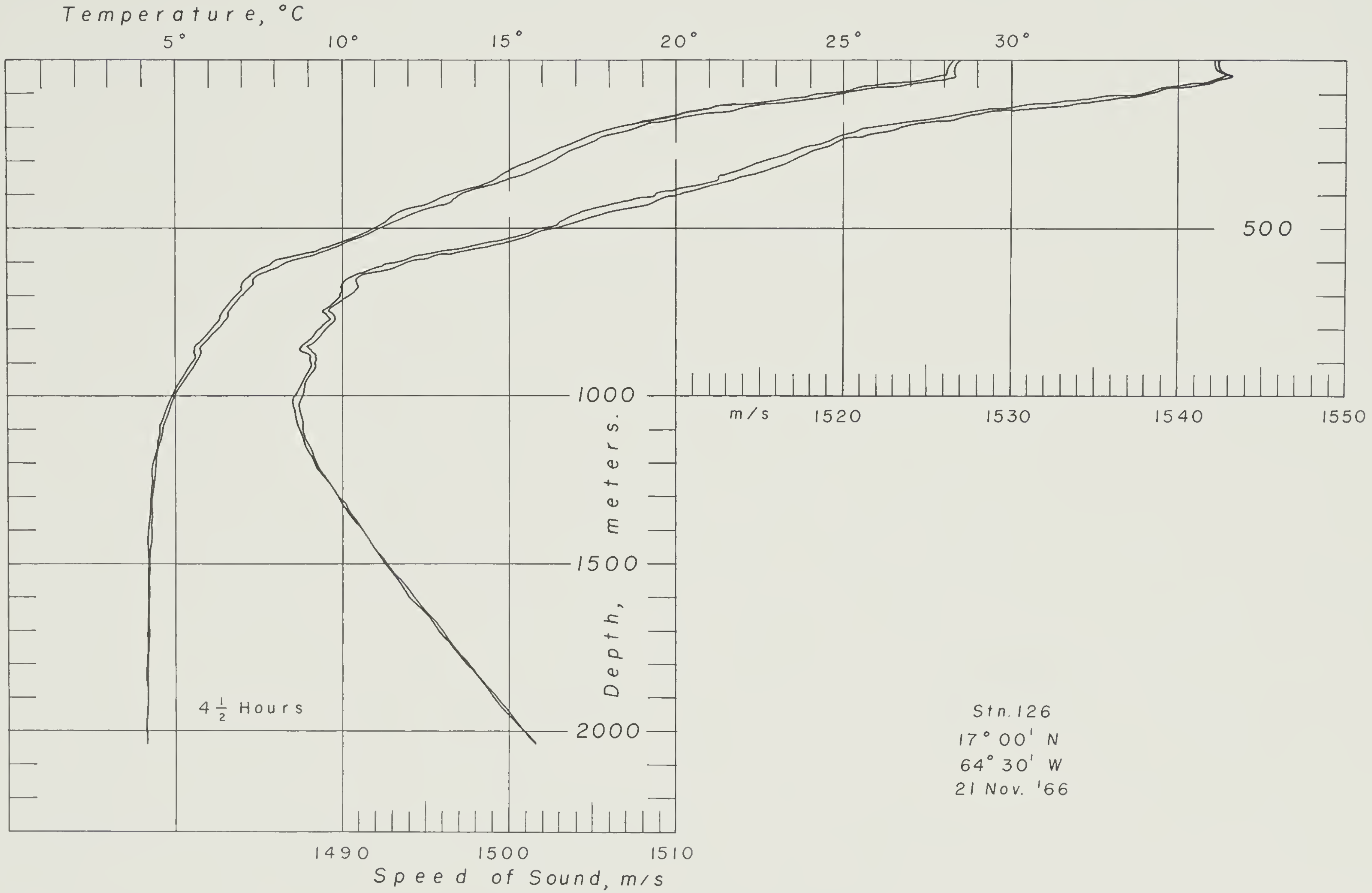


Fig. 46 *Envelope of Profiles* - Station 126

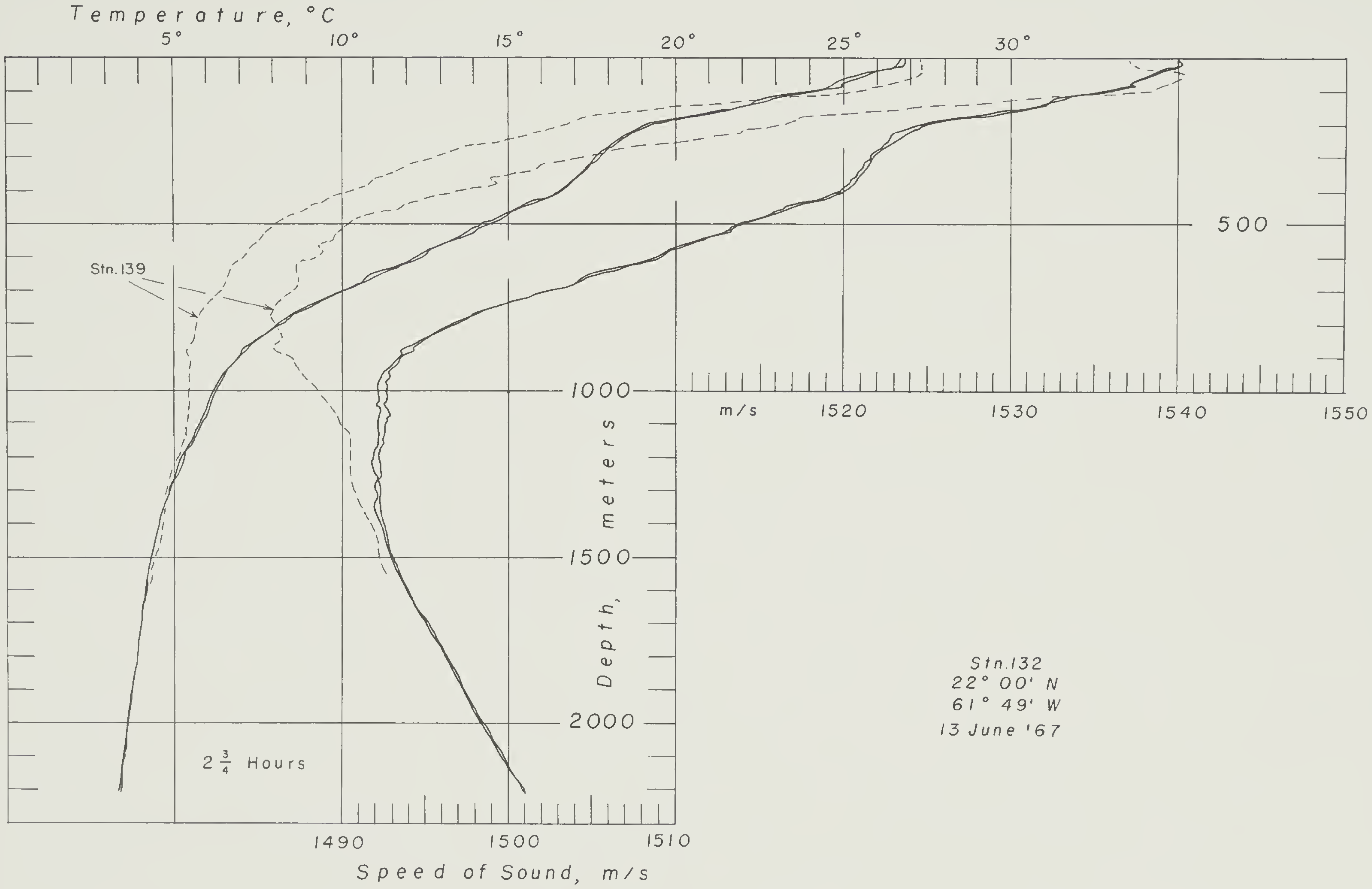


Fig. 47 Envelope of Profiles - Station 132

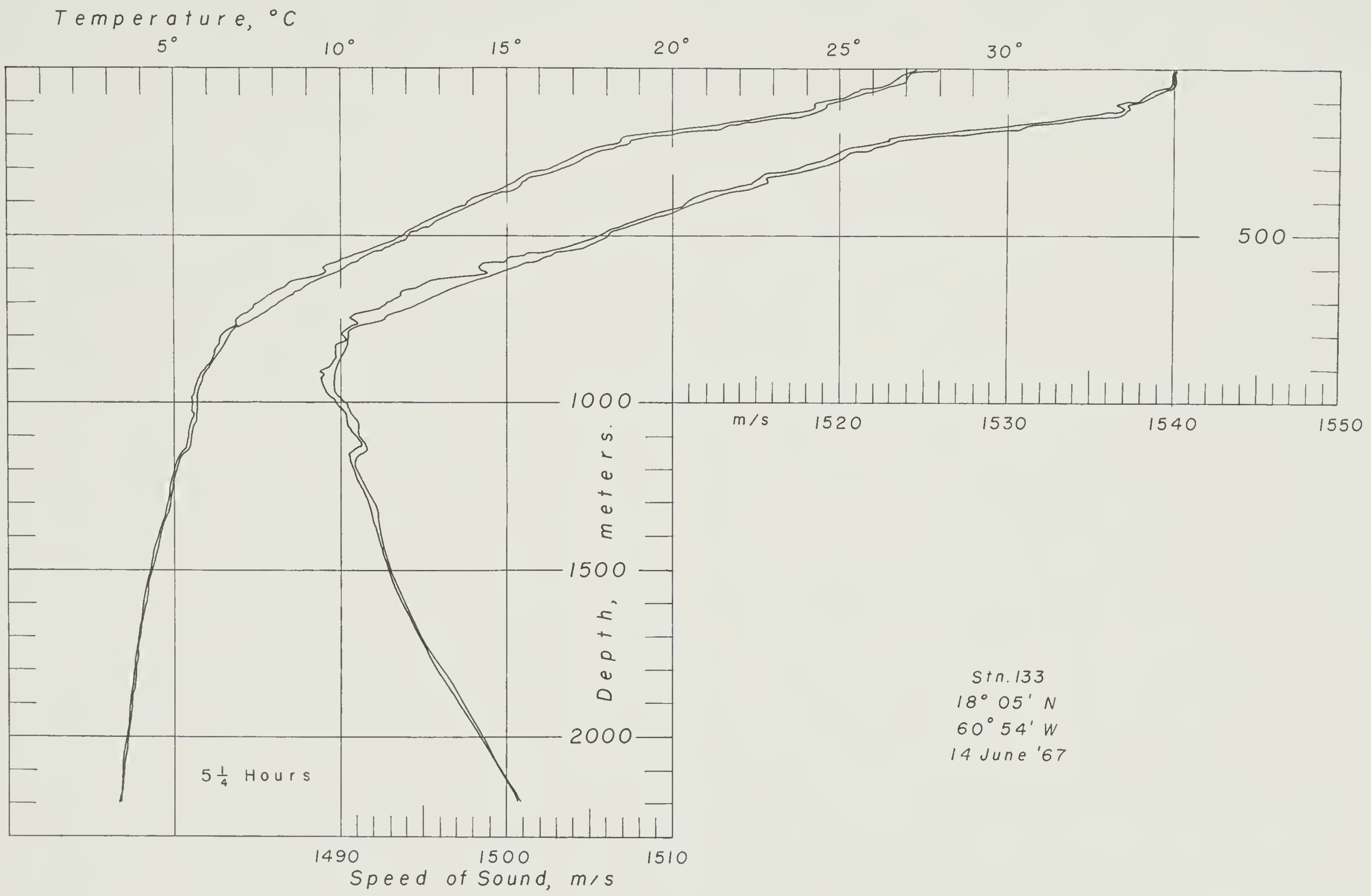


Fig. 48 *Envelope of Profiles* - Station 133

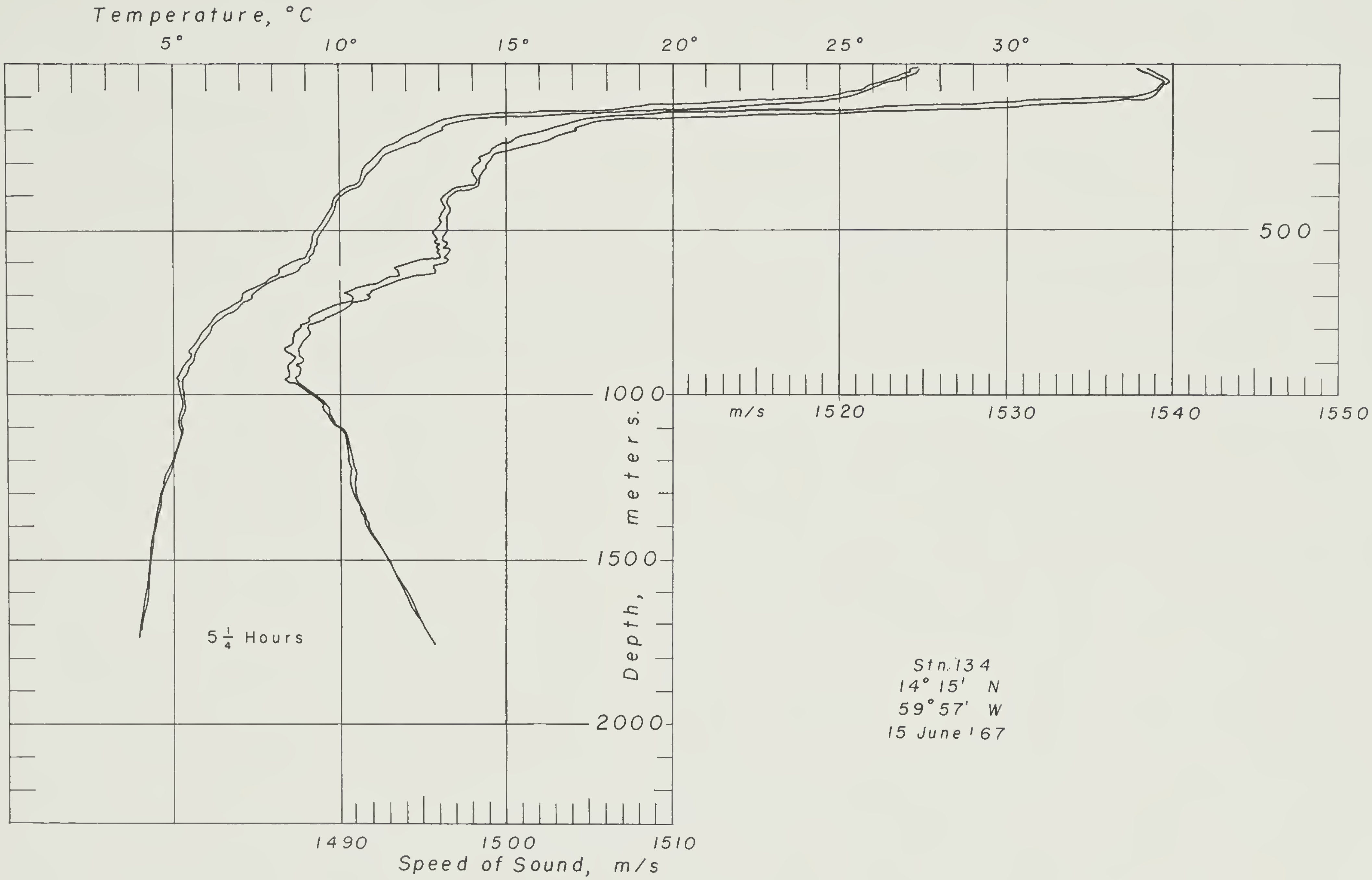


Fig. 49 *Envelope of Profile* - Station 134

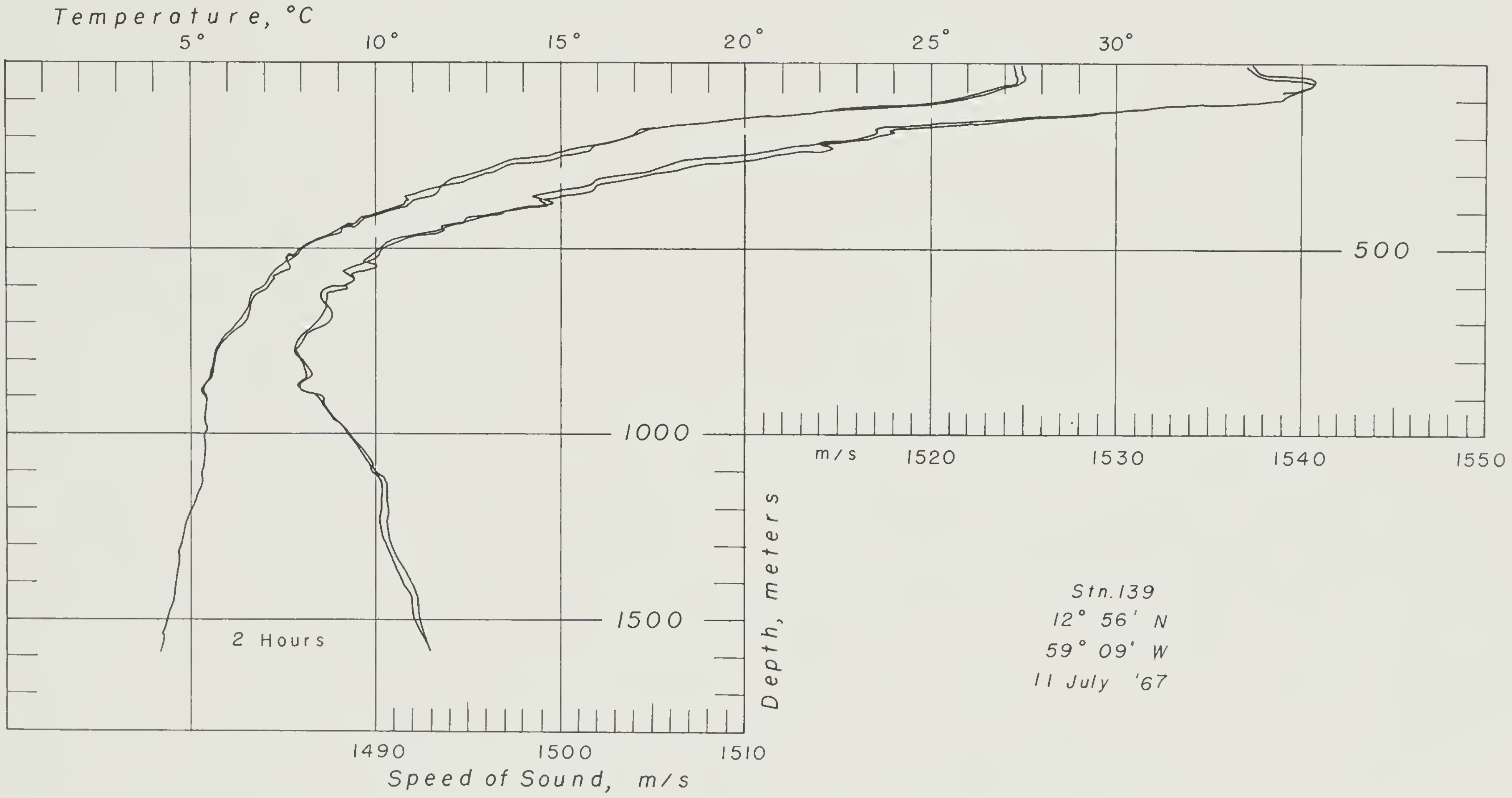


Fig. 50 *Envelope of Profiles - Station 139*

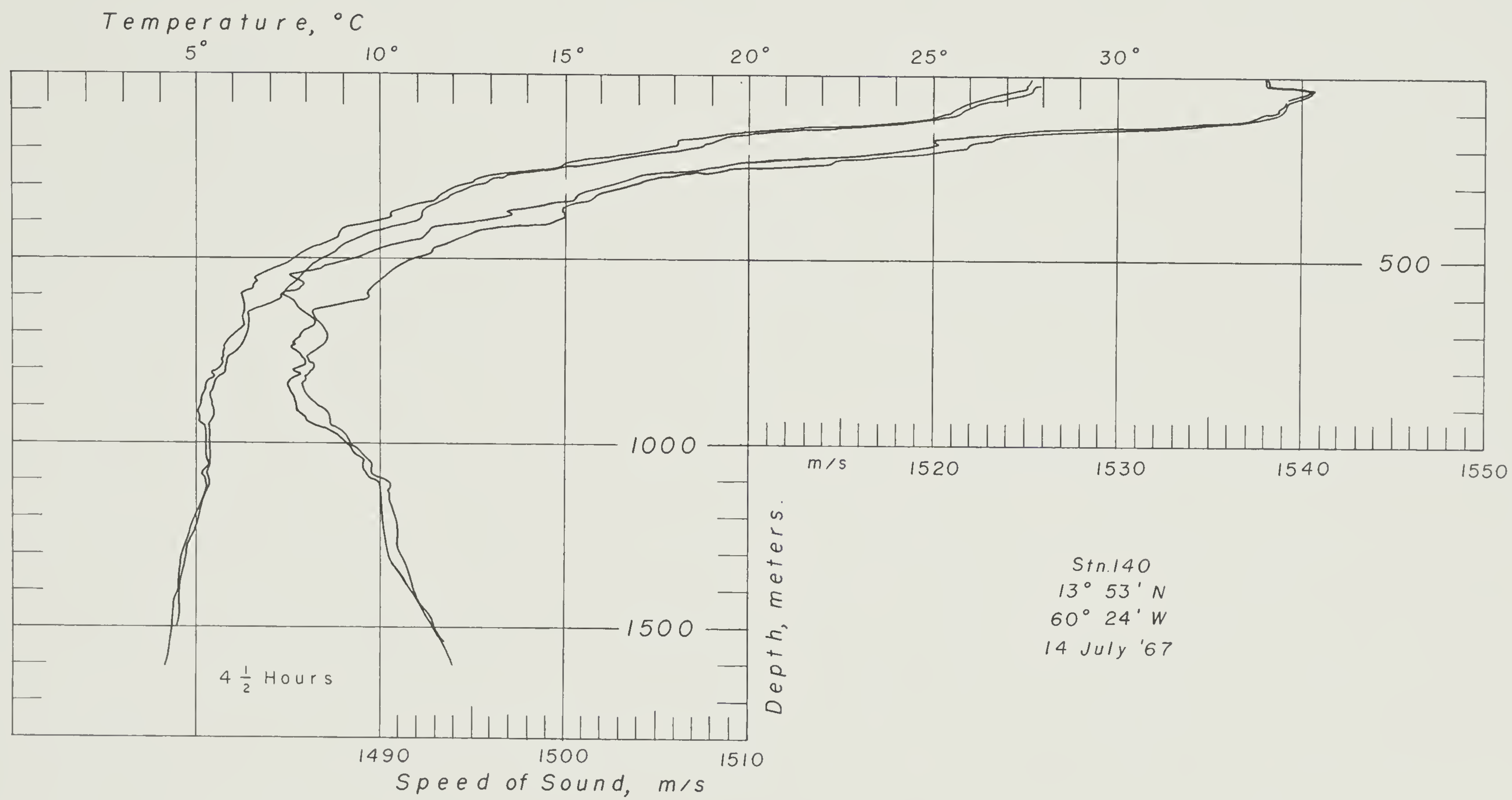


Fig. 51 *Envelope of Profiles* - Station 140

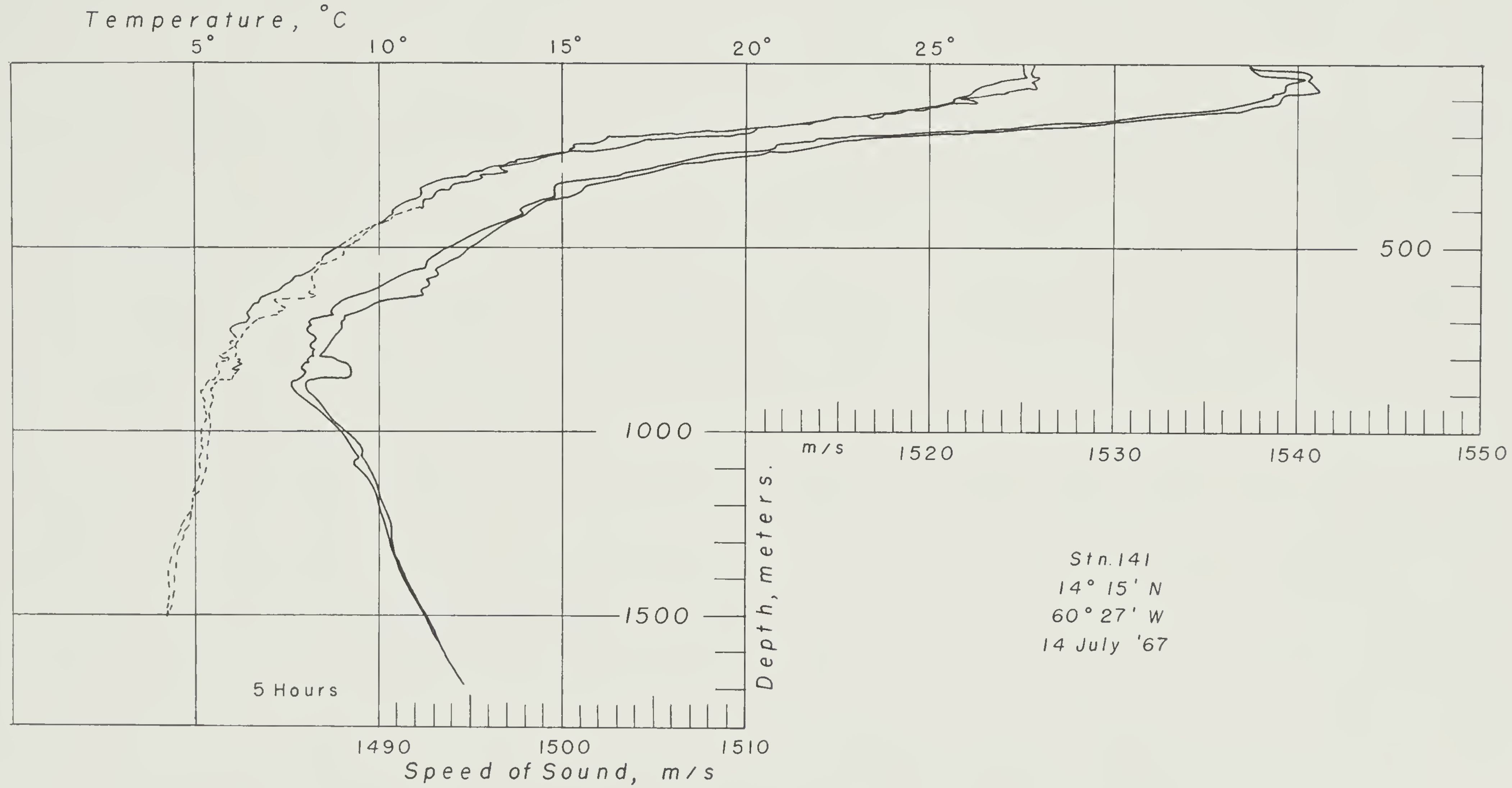


Fig. 52 *Envelope of Profiles* - Station 141

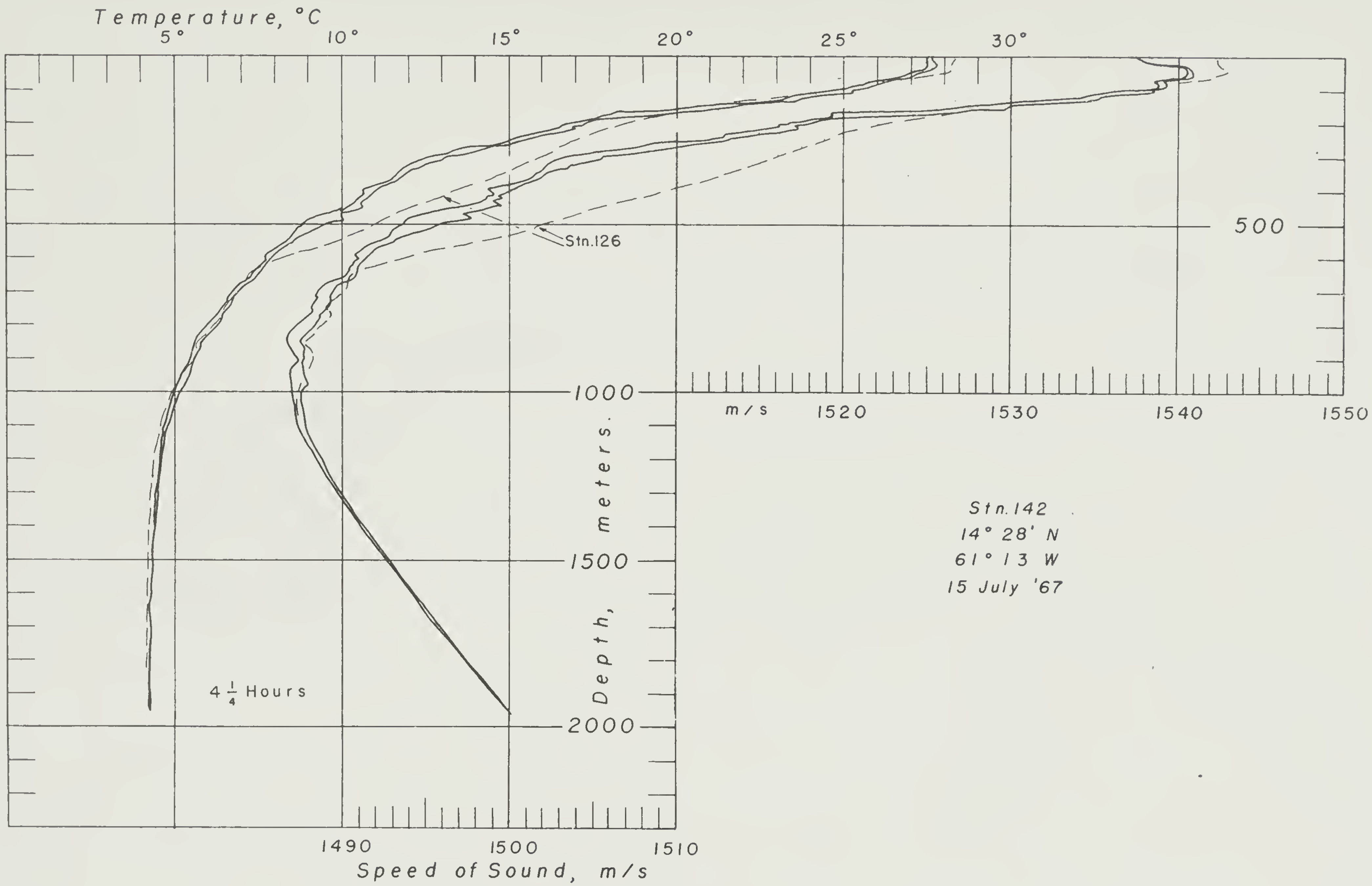


Fig. 53 *Envelope of Profiles* - Station 142

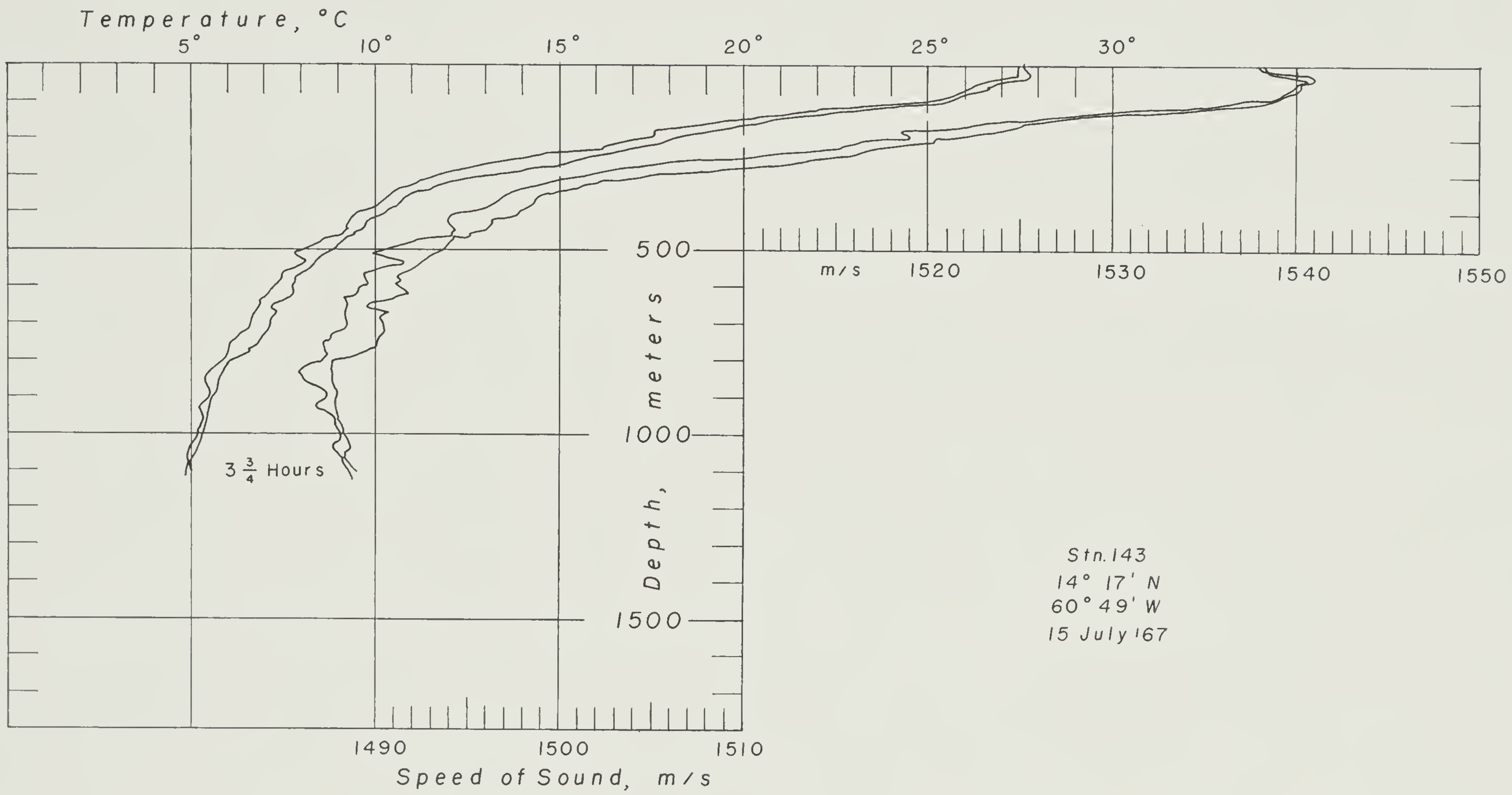
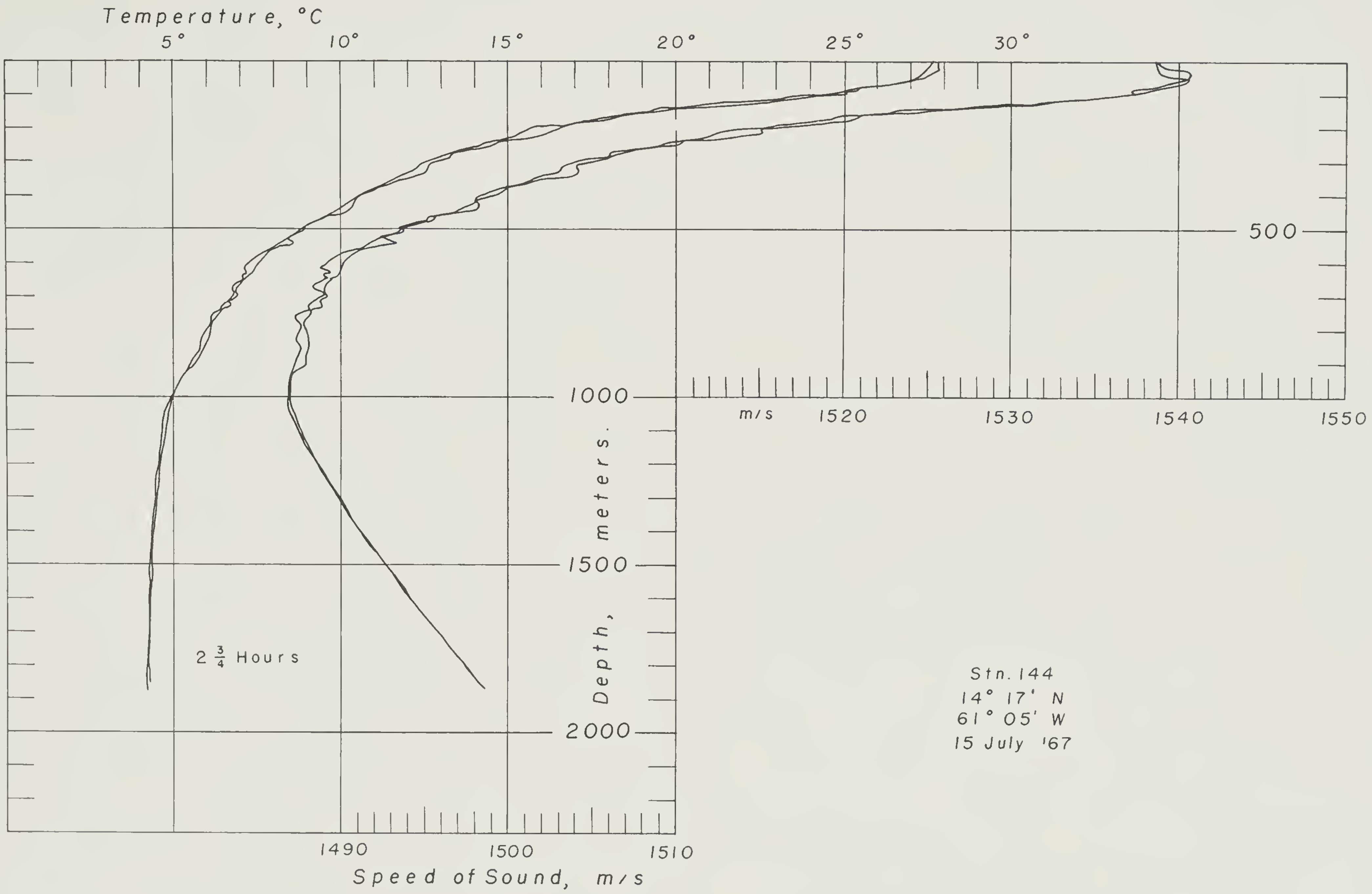


Fig. 54 *Envelope of Profiles* - Station 143



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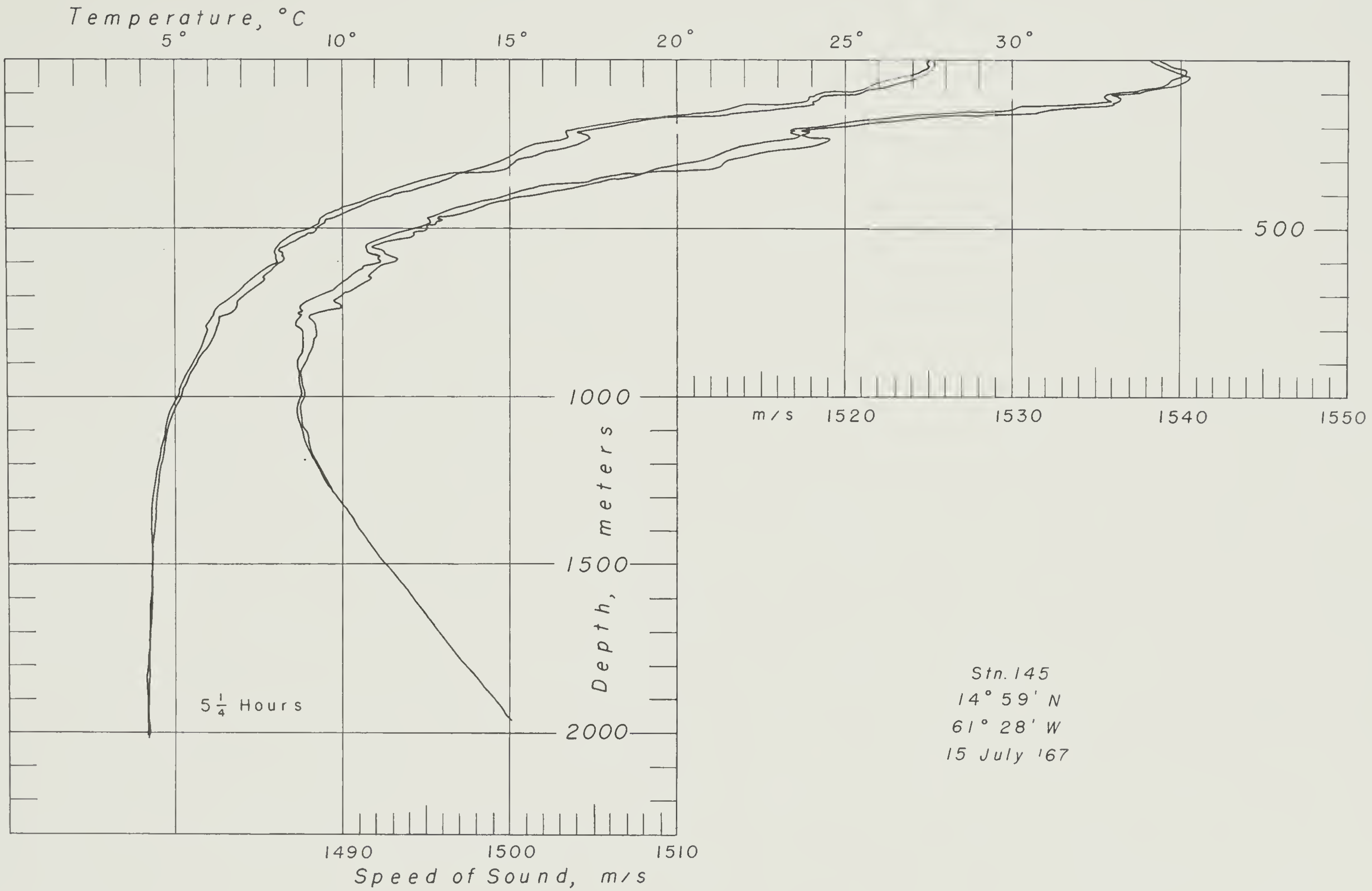

Fig. 56 *Envelope of Profiles* - Station 145

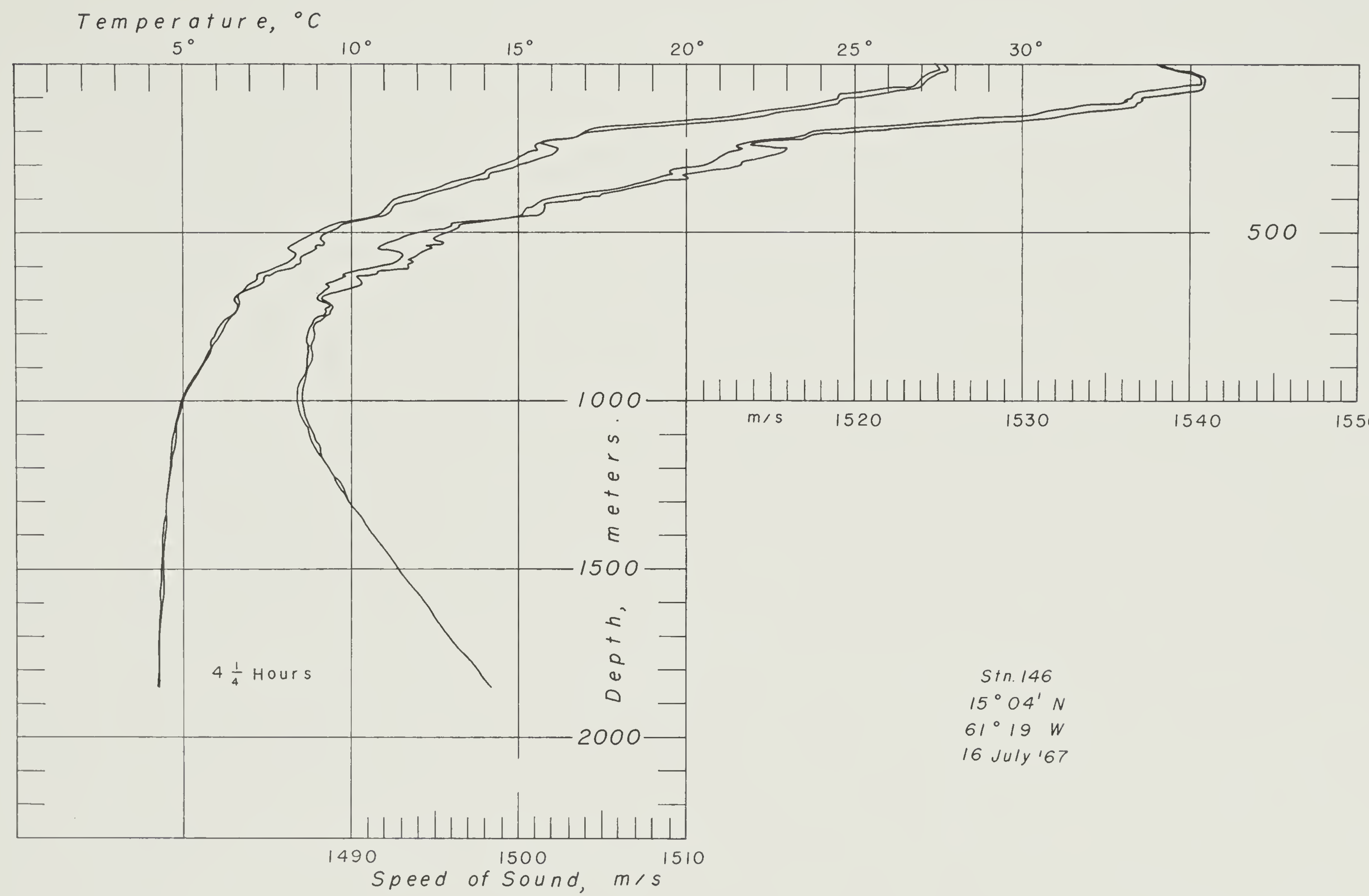

Fig. 57 *Envelope of Profile* - Station 146

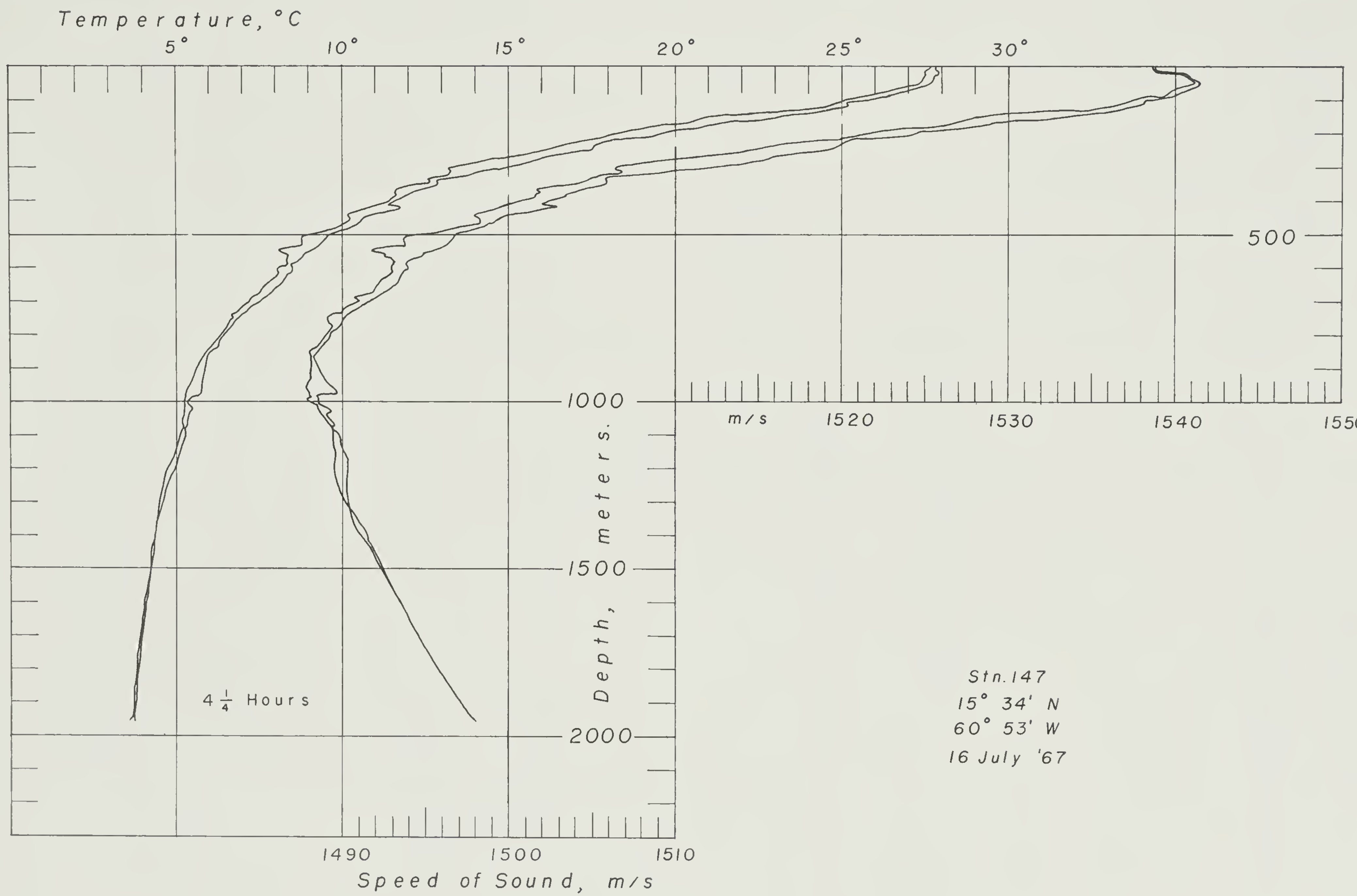

Fig. 58 *Envelope of Profiles - Station 147*

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13. ABSTRACT

High precision, high resolution sound speed and temperature profile sequences are presented for 7 near-synoptic stations in the Anegada passage region; 8 near-synoptic stations in the deep passages adjoining Martinique (St. Lucia and Dominica channels); and 4 stations in the Atlantic about a degree east of the Antillean islands. Microstructure of the waters and short-time variability are emphasized.

Stratification and variability in the passages and the Atlantic nearby are more intense than in the Caribbean.

The characteristics of the Anegada region are intermediate between the Caribbean and the Atlantic. A distinct inflow of Atlantic waters occurs at a kilometer's depth.

Around Martinique the waters are extremely stratified and very confused, the Caribbean dominating nearly to the eastern side of the passages. At the time of this report, the region was influenced by a cold water mass between 160 and 600m depth. This unusual transient water mass, centered east of St. Lucia, is described.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Oceanography Unverwater acoustics. Sound Speed: consecutive detailed profiles, profile envelopes Temperature: consecutive detailed profiles, profile envelopes Oceanic microstructure Caribbean, Eastern Caribbean Passages Anegada Martinique						

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